Diversity in Homegarden Agroforestry Systems of Southern Ethiopia

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Tropical Resource Management Papers
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59

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Tropical Resource Management Papers,
ISSN 0926-9495

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Documents sur la Gestion des Ressources Tropicales, ISSN 0926-9495

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Tropical Resource Management Papers, No. 59 (2005); ISBN 90-6754-901-0

Also published as thesis (2005), Wageningen University ISBN 90-8504-163-5

Diversity in homegarden agroforestry systems of Southern Ethiopia

2005

To

my late parents, Worknesh Teklu (mother) and Abebe Amdie (father)

and

my wife Tigist Tadesse

Preface

Integrated landuse systems such as agroforestry homegardens are believed to enhance agricultural sustainability due to the intimate association between a multitude of crops, trees and livestock which provide various ecological and economic benefits. The traditional agroforestry homegardens of Southern Ethiopia are one such stable agroecosystems which support a very dense population of up to 500 persons per km^2. These systems have contributed to improvements in food security, regional and national economies and environmental resilience. However, they have generally been less studied. An in-depth analysis on the components of the systems and how they function is important in order to propose options for their improvement. The present study, which aims at analyzing the diversity and composition of species in the systems, is believed to contribute towards the filling of this gap.

I am grateful to Wageningen University for granting me a sandwich PhD fellowship. I also thank Debub University, Awassa College of Agriculture for allowing me the study leave. My heart felt gratitude goes to my promoters, Prof. Marius Wessel, Prof. Frans Bongers and co-promoter Dr. Freerk Wiersum for their scientific guidance, patience and untiring support during the course of the study. Outside the academic life, they have cared about my social life in wageningen. I thank you all for your kindness and hospitality. I am also grateful to Dr. Frank Sterk for his unreserved support in data analysis. The Forestry chairgroups of Wageningen University and the foundation "Sharing Responsibility for Students" have covered my allowance for the extra months needed to complete my thesis in Wageningen. I am very grateful for this support. The staff of the chairgroups has also been cooperative, warm and friendly. I thank you all.

The field research was supported by the International Center for Research in Agroforestry (ICRAF), presently renamed as World Agroforestry Center. I would like to present my deepest gratitude to ICRAF for its generous financial support. I am particularly indebted to Prof. August B. Temu, leader of the Training and Education program and my supervisor from ICRAF side, for facilitating the acquisition and management of the fund, and for his scientific advice during his visit of the research sites.

Different organizations and individuals have contributed to the realization of this thesis. I am grateful to the Agricultural Bureau of the Southern Nations' Nationalities and Peoples Regional State and the then head of the bureau Ato Lemma Mitiku, the Sidama zone agricultural office and the woreda agricultural offices of Aleta Wondo, Dara, Dale and Awassa Zurya for facilitating my study in the areas. I am also indebted to the Peasant Association leaders of the 12 research PAs. Agricultural technicians working in the respective woredas have assisted me in data collection, and I would like to thank all of them. My sincere appreciation goes to Teshome Gulte of Dale, Genene Lulseged of Aleta Wondo and Mermera Worga of Dara for their determined efforts and meticulous manner of data collection. The field study would not have materialized without the support of the good-hearted Sidama farmers. I would like to sincerely thank the sample households and for allowing us to collect data from their farms and provide us with the necessary information.

Despite my busy schedule, I have enjoyed my stay in Holland thanks to the hospitality of; my friend Job de Klein and his family, the family of Prof. Frans Bongers and my Ethiopian friends. Thanks a lot!

In Awassa, my friends have been a constant source of encouragement and support to me and my family in good and bad times. I am grateful to all of them, especially the families of Gerawork Zeleke, Dr. Sheleme Beyene, Dr. Bizuayehu Tesfaye, Dr. Admasu Tsegaye and Gashaw Meteke. The families of my sister Yeshiwork Abebe, my brother Dr. Bekele Abebe, my mother-in-law Yeworkwuha Beyene and the family of Teklu W/Mariam have always stood with us to share our problems. I thank them all.

My dearest gratitude goes to my wife Tigist Tadesse for her patience, wholehearted support and encouragement during the course of the study.

I would also like to express my profound gratefulness to my dear parents; my late mother, Worknesh Teklu and my late father, *Memire* Abebe Amdie (who passed away a few months ago) for their selfless and honest upbringing, and for letting me to strive towards the realization of my potentials. May God bless their soul.

Finally, I would like to thank the almighty God for helping me throughout my life including in the realization of this thesis.

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CHAPTER 1

1. General introduction

1.1 Tropical homegardens

Small-holder farming systems in the tropics are faced with constant pressure of change brought about by demographic, economic, technological and social pressures. Population growth, increasing commercialization of products and the use of modern inputs are the most important factors that contribute to landuse changes. In many tropical countries, agricultural landuse changed following the trajectory from hunter-gatherer life style in rainforests to market oriented monoculture systems resulting in increased higher per capita food supply at the global scale. Thus, the hunter-gatherer lifestyle supported about 4 million people globally but modern agriculture now feeds about 6 billion people (Tilman *et* al., 2002). The commercial production systems at the end of the intensification gradient aim at maximum profitability and they are characterized as high input, open systems with low species diversity. On the other end, the rainforests are almost closed systems with very little input and high species diversity. In between, there are farming systems of intermediate complexity and species diversity that include different agroforestry and intercropping systems (Figure 1.1; see also Wiersum, 1997). In the past, monocropping systems were considered to be the most desirable end-stages of agricultural development since high production of the systems would contribute towards solving the problem of food shortage.

Recently, concerns have developed on the long-term sustainability and environmental consequences of the intensification of agricultural systems. Increasing attention is being given to achieving stability in land utilization on the longer term basis while fulfilling the needs of the local population (Reijntjes *et* al., 1992; Swift and Ingram, 1996; Tilman *et* al., 2002; Matson *et* al., 2002). Notably, in small holder farming systems in the tropics, the use of modern technologies might not be the first option to improve agriculture. In such areas, better use of local resources and natural processes could make farming more effective and create conditions for efficient, profitable and safe use of modern inputs (Reijntjes *et* al., 1992; Altieri, 1995). In response to these concerns, interest in integrated land-use and sustainable agriculture involving the intermediate places of the rainforest-monocropping continuum arose over the recent few decades (Francis, 1989; Nair, 1993; Wiersum and Gonzalez, 2000). One type of such integrated land use systems are the tropical homegarden agroforestry systems.

Along the intensification gradient homegardens come next to rainforests (Figure 1.1). They are the most complex and diverse agroecosystems and this indicates their suitability to fulfilling ecological functions. On the forest-monocropping continuum, homegardens are located far from market oriented commercial production systems but this doesn't necessarily indicate that they are economically less attractive. On the contrary, many homegardens in the tropics are economically more viable than other land use systems in the regions because of the high-value cash crops comprised in them. The coconut dominated homegardens of Kerala (Nair and Sreedharan, 1986; Kumar *et* al, 1994) and Kandy (Jacob and Alles, 1987: McConnel, 1992) and the coffee based homegardens of East Africa (Fernandes *et* al., 1984; Odoul and Aluma, 1990) are examples.

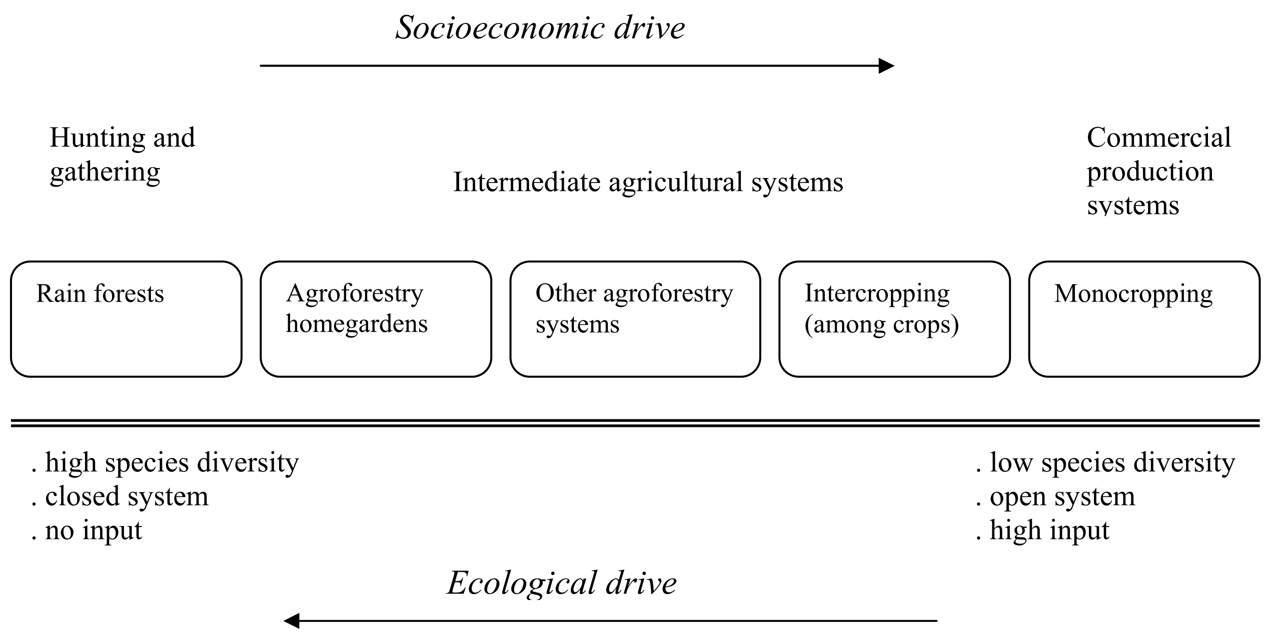


Figure 1.1 A continuum in land-use systems and species diversity along with gradients of ecological and socioeconomic drives of land managers (modified after Anderson and Sinclair, 1993)

In recent decades, several tropical homegardens have been described, although sometimes under other names such as, compound farms (Okafor and Fernandes, 1987), household gardens (Ninez, 1987), house gardens (Padoch and Jong, 1991), kichen or door yard gardens (Rico-Gray *et* al., 1990).

Fernandes and Nair (1986) define homegardens as ‘landuse practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, livestock, within the compounds of individual houses, the whole crop-tree-animal unit being managed by the family labor’. These systems have also been described as a small-scale ‘supplementary’ food production system (Hoogerbrugge and Fresco, 1993), using ‘marginal land and marginal labor’ (Ninez, 1987; Hoogerbrugge and Fresco, 1993). As indicated in the above description, homegardens often are part of a more complex farming system which also include other cropping systems. This, however, is not always the case.

Two types of homegardens can be recognized on the basis of their contribution to the welfare of households. The first ones, common in much of the tropics, are small-scale supplementary food production systems around houses in areas where livelihood of the owners is based on other land use or other activities. This category of homegardens includes a wide range of rural, semi-urban and urban gardens. The renowned homegardens of Java that supplement monoculture rice production (Wiersum, 1982; Soemarwoto, 1987; Marten and Abdoellah, 1988) and most homegardens from Latin America (Padoch and Jong , 1991; Clerck and Castillo, 2000; Mendez and Somarriba, 2001) belong to this category. Urban gardens used to produce vegetables and ornamentals to supplement non-agricultural income of owners also fall in this category.

The second category of homegardens are extended farm fields around houses that form the principal means of livelihood for farming households. Most of the homegardens in the highlands of Eastern

Africa (Oduol and Aluma, 1990; Rugalema *et* al, 1994) belong to this category. Here, the farmers have no additional land, or it is small and supplementary to the homegardens.

Homegardens are found throughout the tropics, but they are more common in the humid lowlands. In addition, they occur also in several tropical highland regions. An overview of the agroecological and geographical distribution of most homegardens in the tropics is given in table 1. Ethiopia is one of the tropical countries where homegardens are prevalent in the highlands. In this country, both types of homegardens exist. In the cereal-crop based farming systems, staple food crops such as tef (*Eragrostis tef* (Zucc.) Trotter), barley (*Hordeum vulgare* L.), wheat (*Triticum sativum* L.) and Sorghum (*Sorghum bicolor* L.) are grown in outer farm fields, while supplementary vegetables, fruits and spices are grown in homegardens. Such gardens are also common in most of the urban areas in Ethiopia. The second category of homegardens is common in the perennial-crop based farming systems of the south and south-western highlands. Here, staple food crops (enset and maize) as well as other cash and food crops are grown in the homegardens and these garden farms make the principal means of livelihood for almost all the households. These homegardens, which function as a total rather than part of a farm system, are the focus of the present study. In the following, the main characteristics of homegardens are discussed.

Structure and composition of homegardens

Tropical homegardens are characterized by vegetation layers (stories), imitating the tropical forest structure. The top storey consists of a canopy of tall trees which reduces radiation and mechanical impact of rainfall, creates a relatively constant micro-climate in the lower layers and through leaf fall contributes to the maintenance of soil fertility. The lower layer features staple food and fruit production (e.g. banana, mango, papaya, etc,) followed by bush level growth (e.g. cassava, maize, peppers, etc.) in the third layer. In-ground and ground-covering species (roots and tubers and others) form the last layer, while climbing species transverse the lower stories (Fernandes and Nair, 1986; Ninez, 1987).

Despite the fact that the spatial arrangement of the species seems to lack order and pattern, compatible species are often mixed (Fernandes and Nair, 1986). Moreover, spatial arrangement in these systems often reflects their functional adaptation in a multitude of factors including utilization of plant-symbiotic relationships through mixed cropping (Ninez, 1987). The structure and composition of homegardens differ across sites depending on the ecological setting and socio-economic functions within different household economies (Wiersum, 1982; Christanty, 1985; Fernandes and Nair, 1986; Soemarwoto and Conway, 1991).

Table 1.1 Distribution and biophysical conditions of selected homegardens in the tropics.

Ecological zone	Region	Location	Altitude (m. a.s.l.)	Rainfall (mm yr^{-1})	Area of home-gardens (ha)	Sources
Humid lowlands	South-east Asia	Java, Indonesia (homegardens)	0 - 700	1000-3000	0.01 - 3.0, average 0.6	Wiersum, 1982; Michon, 1983; Christanty, 1985; Fernandes and Nair, 1986; Soemarwoto, 1987 Marten and Abdoellah, 1988; Jensen, 1993
		Maluku, Indonesia (forest gardens)	0-520	3400		Kaya *et* al, 2002
	American tropics	Mexico (house gardens, kichen gardens, homegardens)	0 - 500	800-5000	0.023 - 0.50	Alvarez-Buylla Roces *et* al, 1989; Rico-Gray *et* al, 1990 Clerck and Castillo, 2000
		Peruvian Amazon			0.007 - 0.73, average 0.05	Padoch and de Jong, 1991
		Guatemala		1500-2000		Gillespie *et* al, 1993
		Nicaragua	450	1500	0.02 - 1.4 average 0.32	Mendez *et* al, 2001
	Africa	Nigeria (Compound farms)	0 - 300	1250-4000	0.2 - 4.0	Fernandes and Nair, 1986; Okafor and Fernandes, 1987
Humid lowlands to mid altitudes	South Asia	Kandy, Srilanka (forest gardens)	200 -1050	1875-2500	0.4 - 2.5, average 1.0	Jacob and Alles, 1987; Fernandes and Nair, 1986; Perera and Rajapakse, 1991; McConnel, 1992
		Kerala, India (homegardens)	0-1000	1000-3000	0.02 - 4.0	Nair and Sreedharan, 1986; Fernandes and Nair, 1986; Kumar *et* al, 1994
Highlands	Africa	North/ N- West Tanzania (homegardens)	900-1900	1000-2100	0.2 - 1.2, average 0.60	Fernandes *et* al, 1984 Rugalema *et* al, 1994
		Uganda (homegardens)	1000-2250	1000-2000	0.4 - 1.5, average 1.0	Oduol and Aluma, 1990
		South-west Ethiopia (homegardens)	1500-2300	1000-2200		Westphal, 1975; Okigbo, 1990
Semi-arid to sub humid areas	Africa	Burkina Faso (Ka/Fuyo gardens)	200-500	700 - 900	0.1 - 0.8, average 0.5	Fernandes and Nair, 1986

Research and development efforts on homegardens

The importance of homegardens to fulfill household needs for a variety of crops is acknowledged, but agricultural scientists have rarely been interested in them. The following excerpt from Fernandes and Nair (1986) could indicate why there is lack of interest among scientists. "*Scientists who are not familiar with the homegardens do not realize the importance and potential contribution of these systems in the framework of agricultural or agroforestry developments. Some others, who are under the influence of the traditional outlook of monocultural systems of agriculture or forestry, consider the homegardens to be very specialized systems adapted to subsistence land use, or* *structurally too complex to be suitable as a model to work with*". Hence, scientific attention has rarely been given to improve these traditional systems.

Similarly, development experts, who always look for technologies that are ‘new’ and can be extrapolated to larger areas of land, did not take interest in the gardens because of their labor-intensive nature, and occurrence in small parcels of land mostly in regions with relatively good rainfall or water availability (Ninez, 1987; Nair, 2001).

Any concerted effort on homegarden development should start with learning about the intricacies of these time-tested systems. In a recent review article, Nair (2001) indicated that although tropical homegardens have provided sustenance to millions of farmers, and prosperity to many households around the world, the extent of scientific studies on these systems have been disproportionately lower than what their economic value, ecological benefits, or sociocultural importance would warrant. He also points out that serious efforts must be made to understand the ecological and economic basis in the functioning of these systems, in order to improve them as well as to apply the lessons to improvement of other systems. The present study will contribute towards a better understanding of homegardens.

1.2 Homegardens of Southern Ethiopia

Extensive areas of traditional agroforestry homegardens exist in the south and south-western parts of Ethiopia. Most of these gardens are located at altitudes of 1500–2300 meters above sea level where moisture and temperature conditions are favourable for agriculture. These gardens are characterised by a unique combination of two native perennial crops: enset and coffee. Enset (*Enset ventricosum* (Welw.) Cheesman) is a herbaceous multipurpose crop, and a staple food for about 10 million people in the region. Coffee (*Coffea arabica* L.) is mainly used as cash crop, but also for household consumption. Other components of these multi-species agroecosystems include chat (*Chata edulis* (Vahl.) Forssk. ex Endl.), a mild stimulant, root and tuber crops, fruits, vegetables, cereals, spices and other crops. Moreover, livestock are kept in the gardens and different tree species are grown to serve productive as well as ecological functions. These gardens are also known as 'enset-coffee homegardens' after the two major components.
The area of enset-coffee homegardens in Southern Ethiopia is not clearly known. Some reports have provided estimated areas of the major crops in isolation, but the agroforestry systems where coffee and enset are grown in association with other crops and trees is not known. According to BODEP (1996) a total area of 1.89 million hectares of land is under cultivation in the Southern Nation's Nationalities and Peoples' Regional State (SNNPRS). Out of these, the area of coffee and enset , and the other crops grown in association with them (such as fruits and vegetables, root and tiber crops and pulses) is estimated at 576,000 hectares (BODEP, 1996). The homegardens constitute most of these areas.

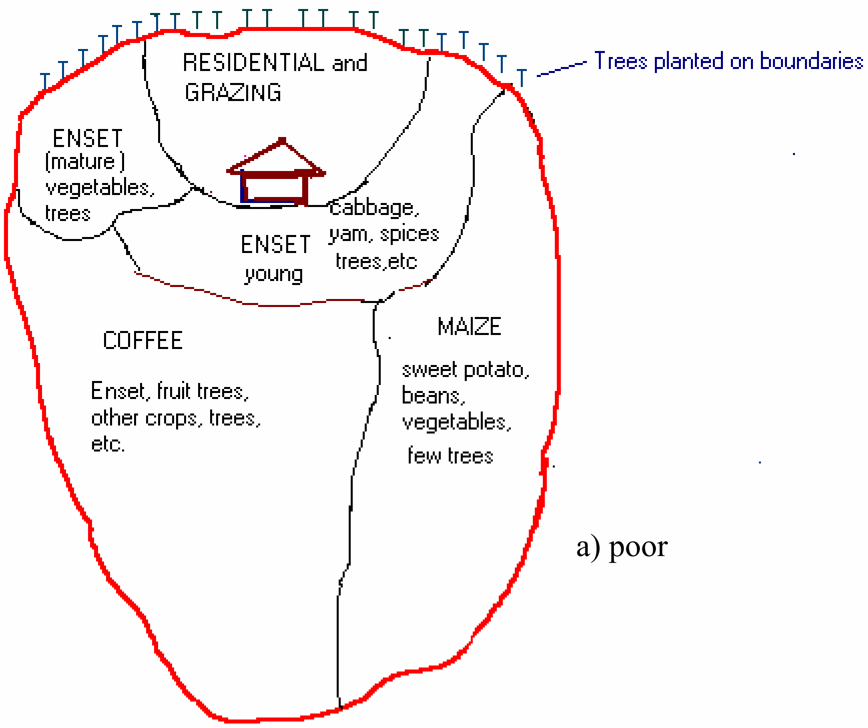
Most of these homegardens have evolved from forests. Farmers maintain the upper storey trees and clear the undergrowth to open up space for planting enset, coffee and other crops. Gradually, more species and varieties of crops and trees are introduced. Partial harvesting of the upper storey trees also takes place to obtain wood and to create favorable growing condition for the other crops.

Presently, most of the forests are used up and there is increasing shortage of land. In these situations some farmers are observed to convert their plot of grazing land into multispecies complex systems.

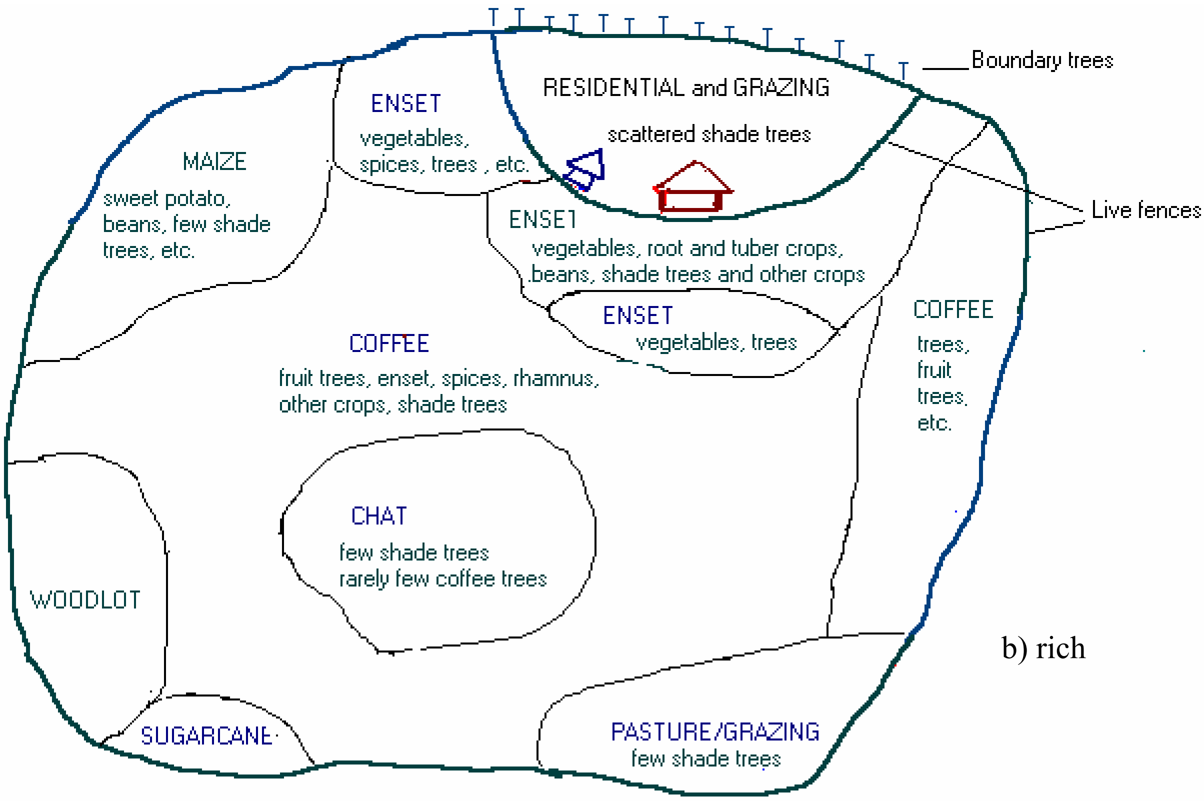
The enset-coffee homegardens have been stable agricultural systems for centuries supporting very dense populations of up to 500 persons per square kilometer (CSA, 1996: Kippie, 2002). The diversity of the systems, and the ability of enset to produce a relatively large amount of food per unit area and time (Admasu and Struik, 2001), could be the main factors that contributed to this stability. Moreover, due to its multi-annual production time and its flexibility on harvesting, enset is an ideal crop to overcome food shortage in drought times (Desalegne Rahmato, 1995). Coffee, which is produced in these predominantly small-holder agroforestry systems is also the major foreign currency earner of the country. Obviously, these agroforestry systems ensure food security in the areas, play a significant role in the regional and national economies, and also contribute to environmental resilience.

One of the characteristics of the enset-coffee homegardens is that they often display a mosaic of patches or farm units which are distinct from one another because of the dominant crop grown on them. For instance, a coffee unit can be recognised where coffee is the dominant crop but grown in association with other crops and trees, or a maize unit that is intercropped with few crops and trees. Near the house, enset is dominant and as one goes further away, other units dominated by coffee, maize, or other crops prevail (Figure 1.2). Marshy areas are often allotted to pastures, sugarcane or eucalyptus.

Westphal (1975), in his study of agricultural systems in Ethiopia, has provided a detailed analysis and description of the systems along with the different crops grown in the region. Okigbo (1990) and Tessema Chekun (1997) have also described these multistorey systems and their major components. ICRAF (1990) has made an assessment on the land use and its agroforestry potentials, and Zemede Asfaw and Zerihum Woldu (1997) have reported on crop association of homegardens in Welayita and Gurage in the region. Kippie (2002) has studied the landuse of Gedeo region. His study aimed at "understanding the theoretical and practical aspects of the holistic Gedeo landuse". He argues that the Gedeo agroforests have a high carrying capacity due to the high productivity of enset and judicious use of accompanying crops. The study indicates that the agroforest land use is suited to the mountainous Gedeo area as it protects against erosion and famine. It highlights that the present productivity of the systems could be enhanced by "carefully redesigning existing composting processes". It also suggests that "finding better marketing channels for the produce of the agroforests is a priority in the short term". However, the question of whether commercialization would affect the structure and composition of the agroforests, is not given attention.



a) poor



b) rich

Figure 1.2 Examples of homegardens and their different units/plots of a) poor and b) rich households

As mentioned earlier, the homegardens reported in this thesis are characterized by the presence of a unique staple food crop, enset. This crop plays a central role in the systems and thus some basic information on its botany and agronomy are given in Box 1.

Recently several important studies on enset have been published. In a review of enset agriculture based in the Wolayita region of Southern Ethiopia, Desalegn Rahmato (1995) pointed out that, enset, as the main staple of the household, is a strategic crop determining cropping plans, land use, use of technology, and consumption and marketing decisions. He noted that if the household has sufficient enset plants established, it will plant crops of high market value. But if this is not the case, cash crops will be curtailed in favor of food crops. He also argues that, the number of enset plants available to the household and their stages of maturity determine the household's decision regarding crop diversification and crop mix. Moreover, he indicated that, despite the high population densities and pressing resource limitations in the enset areas, mobility of the rural population is low due to the inherently high retentive power of the enset system and the prevailing mode of property devolution. Finally, he concludes that, "while in the past population growth may have stimulated change and adaptability in the enset system, the immense demographic pressure in some enset areas (Wolayita, Kembatta and Gamo highlands) today is unlikely to induce technical progress and may in fact drive the system towards technological regression". As it is indicated above, some of the enset areas have reached the limits of their carrying capacity, and the remaining ones are likely to face similar problems in a short time, unless appropriate measures are taken.

Almaz Negash (2001) reported on the diversity and conservation of enset and its relation to household food and livelihood security in the Keffa region of South-Western Ethiopia. The study showed that farmers maintain and enrich diversity in enset, and select or classify clones for various use aspects. The study assessed the role of gender in the production, processing and marketing of enset and found a clear gender differences in these respects. In vitro conservation and propagation protocols were also developed for enset to allow conservation and rapid propagation of disease-free germplasm and for efficient breeding programs. Her study emphasized the importance of genetic diversity in enset and indicated that indigenous knowledge plays a vital role in selection, characterization and maintenance of enset genetic diversity in direct relation to its use.

Bizuayehu Tesfaye (2002) investigated the landrace diversity, in vivo and in vitro regeneration of enset. He reported a total of 86 locally recognized enset landraces in Sidama region of Southern Ethiopia, by using stratified multi-location sampling that covered altitudinal zones of 1600 to 2700 meters a.s.l. He indicated that enset landraces are not evenly distributed across the region mainly due to variations related to elevation. Only few landraces were found to be very abundant and widely distributed. In his study, investigations were also done on in vivo regeneration of enset. The significance of the method for evolutionary advancement and improvement of enset was also discussed. Moreover, a protocol was developed for the cloning of enset in vitro. The study indicated that tissue culture of enset provides new opportunity to control the spread of bacterial wilt disease, which is now threatening enset production, and opens the way to improve enset through breeding techniques.

Admasu Tsegaye (2002) reported on indigenous production, genetic diversity and crop ecology of enset. Indigenous production methods and farm-based biodiversity of enset were analysed in three enset growing regions in Southern Ethiopia. Diverse enset clones ranging from 52 to 59 in number were identified in each region, and the variations in number of clones were attributed to a combination of socioecultural and agroecological factors. In his study, yield potentials of some enset clones were estimated using crop physiological and weather parameters, and actual yield. Moreover, the influence of repetitive transplanting and leaf pruning on dry matter yield and food production was studied. The study also assessed the *Qocho* yield and energy production of enset and found that, in terms of weight and energy per unit of time and area, enset is the highest yielding crop in Ethiopia.

These recent studies on enset cropping systems have clearly highlighted the important roles of enset as a staple food, and its characteristics which allow sustained production even in times of drought (Desalegn Rahmato, 1995; Admasu Tsegaye, 2002). The high genetic diversity is one of the factors that contribute to sustained production. Moreover, the habitus and cultivation techniques provide a permanent soil cover preventing erosion. The studies also provided an insight on the impact of socioeconomic, cultural and physical factors that influence enset cultivation and the use of different clones.

Except in the study of Kippie (2002) little attention has yet been given to the integrated cropping systems in which enset is grown. Still little is known about the diversity and composition of the system components (crops, trees and livestock) and the possible effect of socio-economic and ecological variables on the systems. Moreover, the integrated enset cropping systems are often described as being mainly subsistence-based, and hardly any attention has been given to the question of the possible impact of commercialization on crop diversity and composition. The present study will focus on these hitherto neglected aspects of the enset based landuse systems. Particular attention will be given to the agroforestry systems where enset is grown in association with coffee and other crops.

Box 1. The enset crop

Enset (*Enset ventricosum* (Welw.) Cheesman) is one of the major food crops in Ethiopia. It is sometimes called false banana because of its morphological similarity to the banana plant. However, enset can be distinguished from banana, among others, by its giant size, single-pseudostem structure, dilated bases and erect leaves.

Taxonomy: The genus Enset, which belongs to the family Musaceae, order Zingiberales (Tomlinson, 1969), consists of different species that are distributed in some parts of Africa and Asia, but *E. ventricosum* is economically the most important one (Baker and Simmonds, 1953; Simmonds, 1962). *E. ventricosum* is native to the south and south-western parts of Ethiopia (Smeds, 1955; Harlan, 1969), where it is widely cultivated at present.

Morphology: Enset is a giant herbaceous plant. A mature enset plant has an average height of 4–8 meters, but it could reach as high as 10 meters depending on the cultivars used and site conditions. The average basal diameter of its dilated pseudostem is 0.5-1.0 meter. The pseudostem, which is composed of leaf sheath, has a length of 1.0 to 2.5 meters in fully matured plants. Leaves are large with oblong blades and often long free petiole. The inflorescence grows from the center of plant, and fruits are small with large black non-edible seeds (FAO, 1961; Bizuayehu Tesfaye, 2002). Since enset uses its store of carbohydrates during fructification and eventually dies (FAO, 1961), farmers often harvest it before flowering (see Figure 1.3 for details on the different parts of the enset plant).

Ecology: Enset is cultivated within altitudes of 1500-3100 meters above sea level, in areas having a mean temperature of 10-200C, and annual rainfall of 1000-1800 mm distributed in 8 to 10 months (BODEP, 1997). Temperature plays a significant role in the growth rate of enset. Accordingly, at the altitudinal ranges of 1500-2300 meters (Woyna Dega areas) where mean annual temperature is 15-20°C, enset grows fast and reaches full maturity in 5 to 7 years. On the other hand, in the high altitudes of 2300-3100 meters (Dega areas), where mean temperature drops to 10-15°C, it takes 8-10 years and sometimes up to 16 years (FAO, 1961, Shank and Ertiro, 1996) to reach full maturity. Enset thrives best in fertile, well-drained soils of moderately acidic to alkaline nature (Bizuneh and Feleke, 1966; Admasu Tsegaye, 2002).

Propagation: Under natural conditions enset is reproduced from seeds, but in enset cultivation areas it is reproduced from suckers. The corm of an immature enset of 3-4 years (locally called Simancho) is dug out and the pseudostem cut leaving 10-20cm of the lower part attached with the corm. The center of the corm, which is the base of the inflorescence, is completely cut out to remove the growing bud. Then the corm is buried in a hole and covered with manure and soil. The suckers, which emerge in 4 to 12 weeks, are left to grow for about a year. The corm is then dug out, the suckers (called Funta) separated and transplanted in a well-prepared land. The density of plants in this initial transplanting is about 5000 to 10 000 plants per hectare. After a year or two, some of these plants are thinned out (Duqullo) and transplanted in another place. After this stage, the density of plants is kept at about 1600 to 2500 plants per hectare. Starting from the fourth year enset can be harvested for food.

Products and uses: Enset is a multipurpose crop that produces food, fodder, fiber and other products. Food is extracted from the pseudostem and corm because the starch accumulated in the leaf sheaths and the corm are the main products. Three types of food products are known, namely Qocho, Bulla and Amicho. Harvesting takes place mostly in the dry season, but for some landraces it can take place at any time of the year. During harvesting, the pseudostem is stripped off until the edible part remains, and all leaves are removed. Then, the corm together with the pseudostem is dug out and transported to the processing area, which is often an open space in the plantation with sufficient shade. Here, the leaf sheaths are peeled off one by one and then scrapped with a knife to separate the pulp from the fiber. The pulp is squeezed and the liquid starch obtained from it is collected. The clean white starch obtained after precipitation is a product locally called Bulla. The remaining pulp is accumulated in a pit lined with fresh enset leaves. The corm is also decorticated and added to the pit. The contents of the pit, which require several enset plants to fill, are fermented for some weeks and are ready for immediate consumption or storage. The product obtained from this process is the major product of enset and it is locally called Qocho or Wassa in Sidama. The corm of some enset landraces, which is locally called Amicho, can also be boiled and consumed like Irish potato.

Nutritionally, enset products are rich in carbohydrates but low in proteins and fats (WFP, 1991). Yield of enset varies with the landraces used and with the climate. According to the nationwide survey on enset production (CSA, 1997), the average yield of Qocho and Bulla per mature enset plant is 30.2 and 1.0 kilograms, respectively. Shank and Ertiro (1996), have reported Qocho yield of mature enset to vary from 19.7 to 84.6 kilograms per plant, with the average of 44.2 kilograms at 50% moisture. Admasu and Struik (2001) has obtained Qocho yield of 54 kgs per plant by transplanting the enset twice. It is therefore evident that, even when the lower average yield of about 31 kg per plant is considered, its productivity is about 10 tons-1ha–1yr, which makes it among the highest productive crops in the country. Admasu Tsegaye (2002) has compared the productivity of enset with other food crops grown in Ethiopia and found out that edible yield and energy production of enset per unit area and time was the highest.

In addition to food, enset has many other uses. The fiber extracted during processing is used locally for making strings, ropes and other products, or it is sold in markets for use by fiber factories. The left-over during harvesting as well as the thinnings and leaves of enset are important fodder sources for cattle. The leaves as well as the dry leaf sheaths are also used as packing, wrapping and binding materials. Moreover, some enset landraces are used in human and livestock medicine.

Besides these products, enset plays a very important environmental role. It protects the soil from erosion and runoff, It serves as shade and improves the microclimate for the undergrowth, and the litter from the leaves and other parts improve soil fertility. Unlike annual plants, a small portion of the biomass is taken out of the system during harvest, while the largest portion is returned directly as litter or indirectly through the manure. Finally, enset is an ornamental crop: As some Sidama farmers expressed it, ‘a cottage without enset in its surrounding is like a bird without feather’ simply meaning unattractive or without grace. On the other hand, the giant enset plants around the houses are sources of pride for the owner.

In general, enset has ideal attributes for low-input sustainable agricultural production systems: It is high yielding, it can be harvested any time once it is about four years old, it doesn’t require external inputs, it protects and/or enhances the environment, and it has multiple functions. It is, therefore, no wonder that it has been supporting a very dense population for a long time. Because of its contribution to food security and environmental resilience (Desalegne Rahmato, 1995; Admasu Tsegaye, 2001), enset has received attention from researchers and development workers over the last few years.

As it is indicated earlier, enset grows in wider altitudinal zones of 1500 – 3100 meters a.s.l., but most of it grows at the lower altitudinal zones of 1500-2200 meters in homegarden agroforestry systems. Here, the sites are suitable for different crops, including high value crops such as coffee and chat (*Chata edulis*).

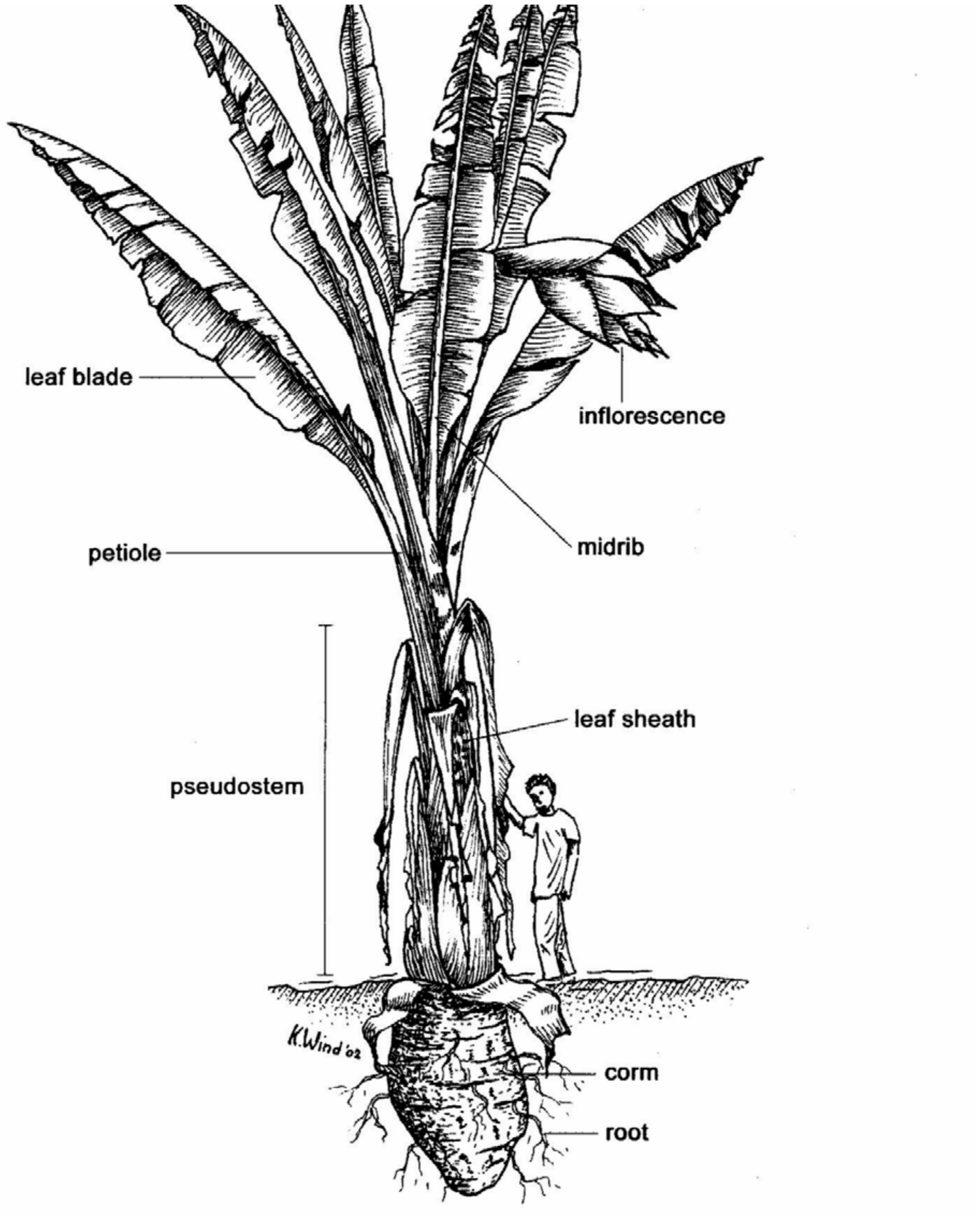


Figure 1.3 Parts of a mature enset plant (Adapted from Admasu Tsegaye, 2002)

1.3 Agrobiodiversity and sustainability

1.3.1 The concept of sustainable agriculture

Agricultural sustainability is defined as ‘the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources’ (CGIAR, 1988).

The definition implies that, to be sustainable,

- a land-use system must generate a level of production that satisfy the material and social needs of the household within certain margins of security and without long-term resource depletion (Conway, 1985, 1987; Wiersum, 1990; Torquebiau, 1992; Reijntjes *et*.al., 1992)
- management practices should be locally adaptable (Wiersum, 1990), and they should ensure conservation of natural resources (Wiersum, 1990; Neher, 1992)
- there should be equitable distribution of inputs and outputs (Conway, 1985, 1987, 1994; Wiersum, 1990; Torquebiau, 1992)

Agricultural sustainability can be classified into two categories: ecological and socio-economic. The former indicates the extent to which natural resources are conserved so that farming would be continued (Neher, 1992), while the latter shows its suitability and adaptability to local farming conditions and its economic viability.

The major strategies associated with agricultural sustainability under conditions of limited resources are (Gips, 1987; Gliessman, 1990; Harrington, 1991; Torquebiau, 1992; Neher, 1992; Reijntjes *et* al., 1992; Nair, 1993; Dalsgaard *et* al, 1995; Altieri,1995; Hansen, 1995),

- self sufficiency through the use of on-farm or locally available 'internal' resources and minimum or conditional use of purchased 'external' resources
- reduced use or elimination of soluble or synthetic fertilizers, increased or improved use of manure and other organic materials as soil amendments, and soil conservation
- reduced use or elimination of chemical pesticides, substituting it by integrated pest management practices and system diversity.
- maintenance of species diversity, as it is important for risk spreading and minimization, genetic conservation of native species, efficient resource use and biological pest control.

Thus, the maintenance of species diversity in agroecosystems is one of the factors contributing towards sustainability. As indicated in chapter 1.1, amongst all agroecosystems diversity is highest in homegardens. In the following paragraphs, the specific features of diversity in homegardens and the relationship between diversity and sustainability will be elaborated.

1.3.2 Diversity of species in homegardens

Agricultural biodiversity (agrobiodiversity), is defined as the variety and variability of plants, animals and microorganisms at genetic, species and ecosystem level involving the whole agroecosystem that is actively managed by farmers (Cromwell *et* al., 1999). The present study mainly deals with the diversity of cultivated species of crops, trees and livestock in homegarden agroforestry systems.

One of the typical features of tropical homegardens is the high diversity of their components. There is a great diversity in the types of trees, shrubs, vegetables and crop species, animals, as well as in the spatial arrangement of these components (Mergen, 1987). For instance, in the homegardens of West Java, 56 species of plants were recorded in a single homegarden and in a hamlet of 41 households the number of species reached 272 (Soemarwoto and Conway, 1991). When it comes to genetic diversity, the presence of up to 100 cultivars of banana was reported from the homegardens of Bukoba, Tanzania (Rugalema *et* al., 1994).

The high diversity of species in homegardens, which combines crops, trees and animals having different uses and production cycles, is considered as an essential component of sustainable agriculture because of the wide socioeconomic and ecological roles it plays in these systems. These roles include:

- year round production of food and a wide range of other products such as firewood, fodder, spices, medicinal plants and ornamentals (Wiersum, 1982: Christanty 1985; Fernandes and Nair, 1986; Soemarwoto, 1987; Marten and Abdoellah, 1988; Gliessman, 1990).
- decreased risks of production failure, increased resource productivity over time, expansion of the amount and quality of labor applied in the farm (Netting and Stone, 1996), and provision of output flexibility and alternative production should unfavorable circumstances develop (Wojkowski, 1993).
- potential to serve as repositories of genetic diversity, besides acting as insurance against pests and disease outbreaks, which may be very severe in monocultural stands (Michon *et* al., 1983).
- avoidance of environmental deterioration commonly associated with monocultural production systems (Fernandes and Nair, 1992), largely due to effective nutrient cycling and relatively small hazard for leaching and soil erosion (Wiersum, 1982; Jensen, 1993).
- provision of materials for breeding of useful new crop varieties (Cromwell *et* al., 1999)
- wider ecological services such as landscape protection, soil protection and health, water cycle and quality and air quality (Cromwell *et* al., 1999).

Factors influencing species diversity

Species diversity and composition of homegardens is influenced by ecological, socio-economic and cultural factors (Wiersum, 1982; Michon *et* al, 1983; Fernandes and Nair, 1986; Mergen, 1987; Soemarwoto, 1987; Arnold and Dewees, 1995). In the present study, the factors that influence species diversity and composition of homegardens will be analyzed.

Physical environment

Altitude and climate are important ecological factors that influence species diversity. Soemarwoto and Conway (1991) in their study on Javanese homegardens have indicated that the diversity of plant species decreased with increasing altitude. This is because of the drop in temperature that could affect the growth of some species. Rainfall and temperature are the two important factors of climate that influence species diversity. Diversity of species increases with increased amount of rainfall and temperature as it is demonstrated for humid lowland tropical areas, which are very rich in species as compared to other ecological zones.

Socio-economic and cultural environments

In this category, two major groups of variables can be distinguished; local (external) environment and household environment (household's resource levels). Among the local environment, commercialization and access to market, reliance on off-farm income, access to inputs and access to off-farm resources are believed to influence species diversity of farms.

Commercialization and access to market often causes a decline in the diversity of species. Homegardens close to market towns, particularly in well-off households, tend to emphasize on high-value cash crops instead of staple foods. On the other hand, farmers tend to compensate their lack of access to markets and resources by producing as much of their consumption from home production as possible (Marten and Abdoellah, 1988; Gliessman, 1990; Shaxson and Tauer, 1992; Kaya *et* al, 2002).

An increasing reliance on off-farm income results in less labor being available on the farm and hence farm level diversity will be low (Arnold, 1987; Shaxson and Tauer, 1992). Changes in the cost and/or availability of inputs such as fertilizer and labor can also influence diversity of a farm system. Increased access to these inputs often results in decreased diversity, as farmers tend to produce more commercial crops.

Access to off-farm natural resources, eg. forests, of farmers is likely to reduce diversity of plants in their farms since they can obtain some of their requirements (eg. wood, medicinal plants, etc.) from the forest.

Household resources

The resources of the household, mainly land, but also labor and capital could affect farm level species diversity and composition. As per capita land-holding increases, so does the diversity of the cropping pattern, although the planting density of each crop falls (Padoch and Jong, 1991; Shaxson and Tauer, 1992; Biggelaar and Gold, 1996). On the other hand, farmers with little access to resources, particularly land, may focus on the production of few staple food crops or trade-off home production of crops with off-farm waged work, depending on their individual comparative advantage.

Differences in culture of the farmers also affect the diversity and composition of species, as reported for the Javanese and Sundanese homegardens in Java (Wiersum, 1982; Michon *et* al, 1983; Soemarwoto, 1987).

Characterization and measurement of diversity

To examine the relationships between socio-economic and ecological variables with species diversity of each farm system (homegarden), it is necessary to quantify and characterize farms according to the overall degree of diversity, and this necessitates measurement of diversity. The number of species in the farm is the simplest indicator of diversity: a standard size farm with many species of crops, trees and livestock is more diverse than the one which grows only a few. However, a more sophisticated measure is needed to compare farms which grow different numbers of species as well as the same number of different crops but with different density (Shaxson and Tauer, 1992). Shannon's index of diversity (Shannon and Wiener, 1949) and Evenness (Pielou, 1969), which are the most widely used tools to characterize such diversities (Magurran, 1988; Huston, 1995) are used in the present study.

1.3.3 Homegarden diversity and sustainability

Modern monoculture systems, which are characterized by low levels of diversity, could have gains in productivity through improved efficiency in production (Swift and Ingram, 1996), but they have a fragile ecological equilibrium, with control coming from external inputs rather than internal feedback mechanisms (Harrington, 1991).

Agricultural sustainability is often enhanced through system diversity. Diversity of species of crops and trees in agroecosystems fosters recycling of nutrients, increases efficiency in the use of moisture, nutrients, and sunlight, and reduces incidence of weeds, pests, and diseases (Altieri, 1995). The maintenance of soil fertility through decomposition of litter and manuring (Wiersum, 1982; Ninez, 1987; Hoogerbrugge and Fresco, 1993) and the low export of harvested products (Nair, 2001), which are all associated with the diversity and density of species, contribute towards productivity and sustainability (Wojkowski, 1993).
Increased diversity of annual and perennial species in agroecosystems is therefore considered as an essential component for sustainability. Accordingly, the multispecies homegarden agroforestry systems in the tropics have been producing sustained yields for centuries in a most resource-

efficient way, with a relatively low energy input for establishment and maintenance (Mergen, 1987). They are considered as economically efficient, ecologically sound and biologically sustainable agroforestry systems (Fernandez and Nair, 1986). As discussed earlier, in the past it was often considered that such biodiverse systems would gradually be replaced with monocropping systems. At present, however, the merits of these highly diverse land-use systems are receiving increased attention due to ecological and economic reasons. The major reasons are (Wiersum and Gonzalez, 2000), a) the recognition that biodiversity conservation should not only focus on wilderness areas, but also on landscape niches characterized by high human-selected biodiversity b) the interest in development of multifunctional land-use types which offer scope for contributing towards ecologically balanced land-use patterns, and c) the need for new approaches in agricultural development based on endogenous land-use management systems.

1.4 Problem statement and research questions

Homegardens are variable with regard to species composition, management practices as well as the prevailing biophysical and socioeconomic environment. As indicated earlier, some scientists have described the enset-coffee agroforestry homegardens of Southern Ethiopia, but a detailed analysis of their diversity, species composition and productivity is still missing. Only when this vital information is available, constraints and options for their improvement can be proposed. Moreover, as land-use is not static but changes over time, also the main factors causing these changes should be identified and their effect quantified before recommendations regarding improvements can be made.

Diversity of species of crops, trees and livestock in homegardens has several ecological and socioeconomic benefits. These agrobiodiversities are influenced by different physical and socioeconomic factors (Figure 1.4). Both species diversity and composition of homegardens in turn influences ecological sustainability (ie. stability and resilience) and socioeconomic sustainability (ie. adaptability) of the systems, and this will eventually influence land-use sustainability.

Three main components of biodiversity can be distinguished in homegardens; crops, trees and livestock. This distinction is partly conventional in a sense that it is related to the well-established scientific disciplines of agronomy, forestry and animal husbandry. This differentiation also relates to functional characteristics of the three components. The role of crops is to produce the basic staple food. Trees have specialized production and auxiliary roles, and livestock have roles of protein production and nutrient cycling. Among the crops, a general distinction can be made between food and cash crops. However, this distinction is not absolute in the present study area. For instance, coffee is a cash crop, but it is also consumed at home. On the other hand, staple food crops such as enset and maize can also be sold when production is in excess, or when cash requirements are not fulfilled by selling other crops.

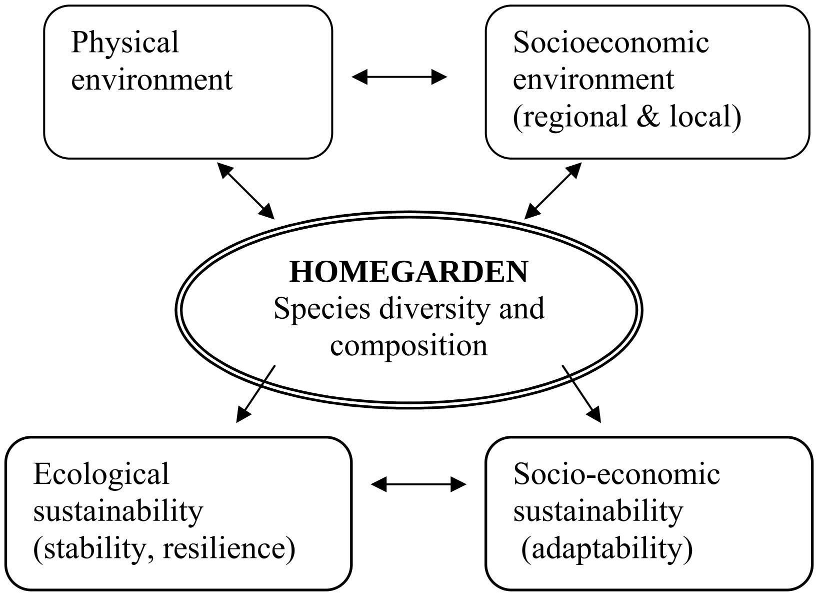


Figure 1.4 The relationships of homegardens species diversity and composition with the local environments and with ecological and socioeconomic sustainability (Framework for analysis).

Among the factors that influence the diversity and composition of crops in homegardens, improvements in marketing and road infrastructure, and increasingly smaller landholding which results from population growth, are expected to have major impacts. Some of these effects are hypothesized in Figure 1.5.

A. The presence of different species of crops fulfilling the dietary, cash and other needs of farmers contributes to nutritional and economic wellbeing of farmers. Access to market and road reduces crop and tree species richness of farms (homegardens) because farmers are likely to focus on few, high value commercial crops for marketing.
B. Decreasing farm size is also expected to reduce species richness because small land-holders attach priority to producing essential staple food crops on the available land.
C. Access to market and road could reduce the area share of food crops, and increase the share of cash crops. This is because the market access enables farmers to give priority to few profitable crops for the market, and purchase the others.
D. When farm size decreases, farmers tend to prioritize production of annual food crops for subsistence. The share of perennial food crops such as enset is likely to decrease because they occupy land for longer duration, and this is in conflict with the immediate food demands of farmers. The share of cash crops could also reduce because priority is given to production of food crops.
E. Trees are often integral parts of agricultural systems in the tropics as they play a multitude of productive and protective roles. The presence of many species of trees with different functions (such as firewood, timber, household utensils and implements, food, fodder, medicine, income generation, erosion control, soil fertility maintenance, etc.) and in sufficient quantities, contributes to agricultural sustainability. Access to market and road could reduce the diversity and volume of trees in farms because of the focus on commercial crops. On the other hand, the share of fast growing commercial trees, such as eucalyptus,

could increase for household use, and also for marketing. Road access is particularly very important for marketing of wood products since it facilitates long-distance transportation.

F. Decreasing land holding could also affect negatively the diversity and volume of trees because the available land is used predominantly for production of food crops. High quality timber species are likely to decrease because they take long time to mature, and the share of fast growing trees could increase mainly for household use.

G. Livestock, such as cows, sheep, goats and poultry provide protein supplement to households and contribute to income generation and livelihood security. Often, butter and egg are marketed, and the animals mainly sheep, goats, heifers, bulls and rarely cows are sold whenever the need for cash arises, and when fodder is in short. Another important role of livestock, particularly cows, in these systems is the provision of manure for soil fertility maintenance. When land holding is getting smaller, the number of large livestock such as cows is likely to decrease because grazing land and fodder will be in short supply. Since enset culture is highly dependent on animal manure, reduction in quantity or absence of manure would result in drastic yield reduction. This will force small-holders to reduce the area share of enset in favor of annual crops such as maize. This shift in land use could in turn affect sustainability of the systems.

The combined impacts of such developments in land use could result in evolvement of new prototypes of the systems. Moreover, the changes in the diversity and composition of crops, trees and livestock in homegardens could have a profound effect on both ecological and socioeconomic sustainability of the systems. Together, they influence land-use sustainability.

The present study deals with these relationships, but the main focus is on the species diversity and composition of the enset-coffee agroforestry homegardens of Southern Ethiopia and at identifying the factors that affect their dynamics in their composition. Moreover, it will investigate whether the relative composition of the main functional components changes during the process of change of the homegardens. Finally, it attempts to assess the implications of these changes for agricultural sustainability.

The main research questions of the study are:

1. What is the diversity, composition (area share) and productivity of crops at farm and regional level, and what changes are taking place in the land-use?
2. What factors influence farm-level crop species diversity and area share of major crops?
3. What is the diversity, density and composition of trees at farm and regional levels, and which factors influence them?
4. What is the amount of standing stock of trees in these systems?
5. What is the productivity of the different homegarden types?
6. What conclusions can be drawn from the above information with respect to agricultural sustainability?

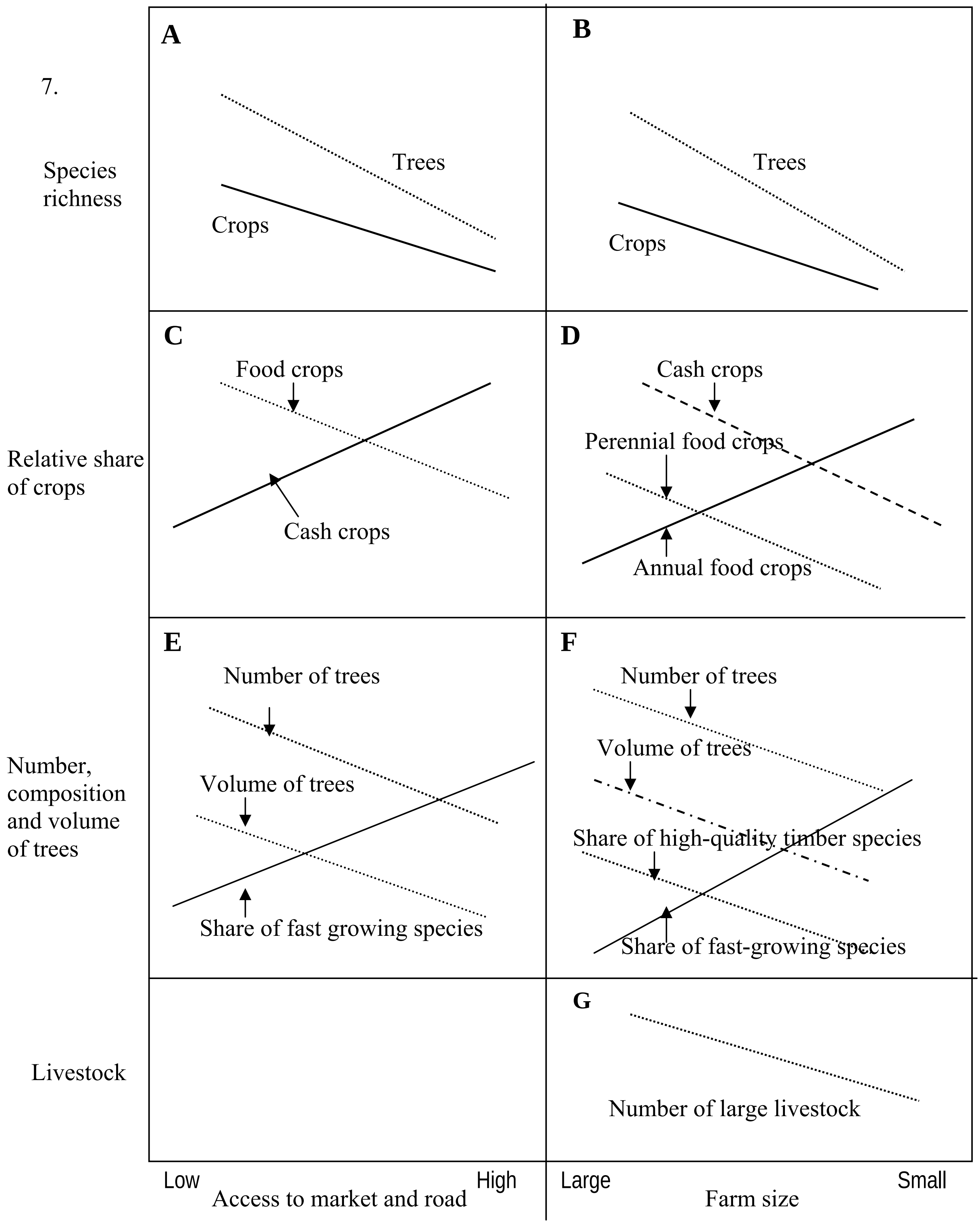


Figure 1.5 Developments in socioeconomic and demographic factors and expected effects on species diversity and composition of homegardens

1.5 Outline of the thesis

In chapter two of this thesis the general research methodology is given. It provides information on the biophysical and socioeconomic environments of the study areas and on procedures followed in selection of the research sites, and it highlights the methods of data collection and analysis.

In chapter 3 crop species diversity of the homegardens and the variations across the different sites are characterized. It investigates also plot level crop diversity, the diversity in functional groups of crops, and compares productivity of crops across the different sites (research question 1). Chapter 4 focuses on socioeconomic and ecological factors that influence crop diversity and area share of major crops (research question nr. 2). Chapter 5 describes and analyses the diversity, density and composition of tree species (research question 3). It also relates diversity and composition of trees to the different sites, and analyses the factors that influence tree diversity. In chapter 6 the standing stock of trees in the homegardens and the patterns of tree growing (research question 4) are presented in detail. It investigates wood supply potential of the different homegarden types and the distribution of trees within the farm fields.

Finally, in chapter 7 species diversity of the different components (crops, trees and livestock) are linked and related. The results are summarized and the productivity of the homegardens assessed (research questions 5). The implications of this information for agricultural sustainability (research questions 6) are discussed and overall conclusions are drawn.

CHAPTER 2

2. Research methodology

2.1 The study area

Ethiopia has a total area of 1.12 million square kilometers stretching between 5-15^0 N latitude and 33-48^0 E longitude. Its altitude ranges from 120 meters below sea level to 4620 meters above sea level resulting in a diverse agroecological conditions ranging from desert landscapes to alpine zones (EMA, 1988). Based on the national census of 1994 (CSA, 1996), the current population of Ethiopia is estimated to be about 70 million.

The Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) is one of the federal states of Ethiopia located in the south and southwestern parts of the country. The region has a total area of 117,506 square kilometers lying within elevations of 378 to 4207 meters above sea level (BODEP, 1996). The current population of the region is about 14 million people comprised of more than 45 different ethnic groups (CSA, 1996). Different agro-climatic zones exist in the region but the *Woina-Dega* (Moist to sub-humid warm subtropical climate) areas, which are situated between 1500-2300 meters elevation, are the most important in terms of agricultural productivity. Most of these areas in the region are categorized as High Potential Perennial zones where the two dominant perennial crops, enset and coffee are grown in an intimate association with other crops, trees and livestock in multistorey homegarden agroforestry systems. These systems are widely practiced in most of the administrative zones of the region, among which Sidama was selected to carry out the present study (Figure 2.1). Sidama was selected due to the following reasons.

a) It is typical a representative with respect to the enset-coffee homegarden agroforestry systems and the prevailing population pressure in the highlands
b) It is situated close to the home institution of the investigator, and hence his familiarity with the biophysical and socio-economic settings

In the following, some baseline information is presented about Sidama administrative zone. For most of the data presented below, the source is SZPEDD (1997).

Location: Sidama administrative zone is located within 5°45'-6°45' N latitude and 38°-39° E longitude, covering a total area of 7672 square kilometers. It is bounded with Gedeo zone in the south, North Omo zone in the west and Oromiya regional state in the north and southeast. The regional and zonal capital, Awassa, which is located in the northern tip of Sidama has a distance of 273 kilometers from Addis Ababa, the national capital while the southern end at Genale river has a distance of 450 kilometers.

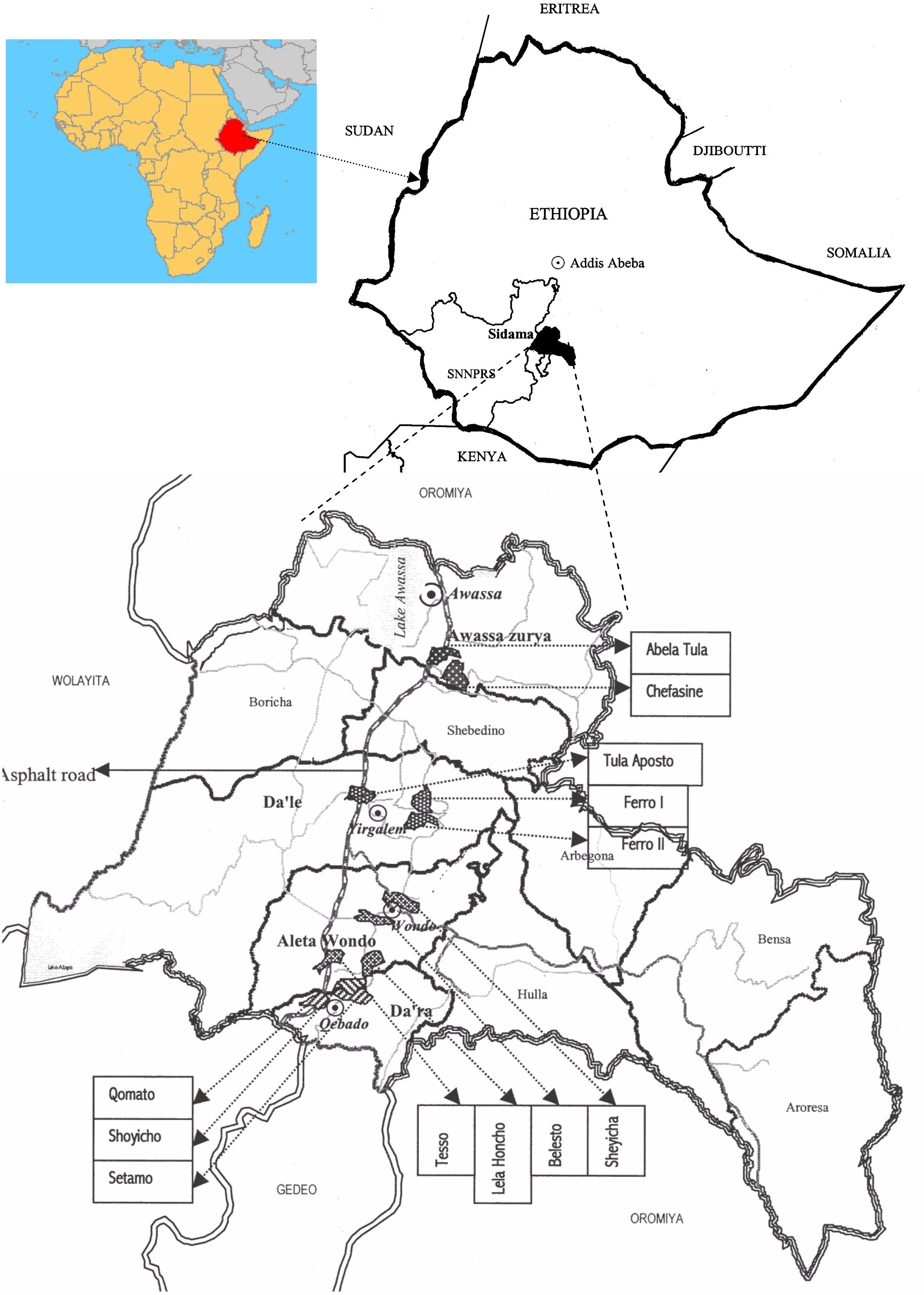


Figure 2.1 Map of Sidama administrative zone showing the research Woredas and Peasant Associations

Soils: Different soil types exist in Sidama. The most common in the Enset-coffee homegardens are eutric nitosols, pellic vertisols, orthic acrisols, chromic luvisols and euctric fluvisols (Table 2.1).

Topography and climate: Sidama zone constitutes diverse altitudinal zones ranging from 500 to 3500 meters a.s.l. Its topography is generally undulating with massifs, plateaus and plains and a number of permanent rivers. A total of 8 rivers, one of which is international, flow in Sidama and none of them is yet exploited. Lake Awassa, with an area of 129 square kms and an average depth of 10 meters, is also present close to Awassa town.

A large portion of Sidama zone receives rainfall for most of the year. The High Potential Perennial areas where the enset - coffee agroforestry homegardens predominate, receive an annual rainfall of 1000 – 1800 mm distributed in 8 to 10 months.

Vegetation: The types of natural vegetation in Sidama include montane evergreen thickets and scrubs, montane dry evergreen forests, montane moist evergreen forests and various types of savanna. In the High Potential Perennial areas where the homegardens are dominant, remnant trees of these evergreen forests are observed among which *Cordia africana, Podocarpus falcatus, Milletia feruginea* and *Bersama abyssinica* are very common.

In general, the combinations of altitude, rainfall and temperature play a role in determining the land use practices. Accordingly, Ethiopians identify five major traditional agroecological zones, three of which are present in Sidama.

Agroecological zones and land use: Three different agroclimatic zones exist in Sidama, each manifesting different land use. These include,

a. '*Qolla'* (dry, hot tropical climate):
These areas lie between 500 and 1500 meters a.s.l., receive an annual rainfall of 400-800 mm, and have a mean annual temperature of 20-25^{0}C. They constitute 30% of the total area of the zone. Here, agriculture is dominated by annual crops such as maize, sorghum and haricot bean, but pastoralism is also an important economic activity.

b. '*Woina Dega'* (moist to humid, warm subtropical climate):
These agroecological zones lie within 1500 - 2500 meters a.s.l., receive an annual rainfall of 1000 – 1800 mm, and enjoy a mean annual temperature of 15-20^0 C. They constitute 54% of the total area of Sidama zone. They are High Potential Perennial cropping areas where the Enset-coffee based homegardens are dominant.

c. '*Dega*' (wet, cool temperate climate):
These areas have elevation of 2500 to 3500 meters a.s.l., receive an annual rainfall of 1200 to 1800 mm, and the mean annual temperature is 10-15^0 C. These areas constitute 6% of the total area of Sidama. Enset is a dominant crop in this zone, but cereals such as barley and wheat as well as vegetables are also widely grown.

Population: Sidama zone has the largest population in the regional state of the Southern Ethiopia. According to the 1994 national census (CSA, 1996), Sidama had a population of 2.04 million people accounting for 18% of the region's total population. Out of this, 92.7% is rural and the remaining of 7.3% is urban. The two consecutive censuses carried out in 1984 and 1994 (CSA, 1996) have indicated that population growth rates in Sidama are 2.2% and 4.1% for the rural and urban areas, respectively. On the basis of these data, the population of Sidama in 2002 is 2.46 million people with a density of 320 persons per square kilometer.

Among the population, 93% belong to the Sidama ethnic group who belong to the linguistic and racial category of the eastern Cushitic peoples (Cerulli, 1956). Other ethnic groups include, Wolayita, Kembatta, Amhara, Gurage and Tigre (CSA, 1996). Sidamgna, which is spoken exclusively in the rural areas, and also in towns, is the working language of the Sidama administrative zone. The age structure of the population shows that 48.9% is under the age of 15 years, 48.7% between the productive ages of 15 and 64 years, and only 2.4% above 65 years of age. The prevalence of a large proportion of population in the unproductive ages of less than 15 years is the result of high birth rate and declining death rate. This demographic feature, which is common in most developing countries, gives an indication on the potential pressure the huge population could exert on the already densely populated systems.

Religion: Christianity is the dominant religion in Sidama. Among the Christians, Protestants of different sects form the majority while there are also coptic orthodox Christians and Catholics. In addition to this, there are Muslims and few with traditional beliefs.

Market: There are two types of markets in Sidama. These are weekly markets that are common in big towns, and traditional markets called *Della* which appear every five days. The weekly markets are bigger and people come from long distances and towns for transaction. On the other hand the *Della* are small and often the basic subsistence items are exchanged within the localities.

Road transport: The presence of roads is an important element in agriculture since it facilitates marketing of produce and delivery of inputs. In this regard, the enset-coffee systems have better road facilities as compared to other agricultural areas, because roads were built mainly to facilitate coffee processing and marketing. Almost all Peasant associations have access to seasonal roads, while all-weather roads connect the *Woreda* towns (see Box 2). Moreover, the highway linking Ethiopia with Kenya crosses five *Woredas* of Sidama. However, most of the farmers in the villages transport their produce on the back of humans or animals and rarely on donkey-pulled carts.

2.2 Selection of the research sites

The Sidama administrative zone is comprised of 10 *Woredas*, most of which exhibit predominance of the coffee-enset homegarden systems. In order to have a fair representation of these systems across Sidama, stratified sampling procedures were followed to collect data at three levels; Woreda, Peasant Association (PA) and households.

Box 2. Definition of terminologies

- A *Woreda* is an administrative unit somewhat equivalent to a district. The area and population of the Woredas differ significantly. In Sidama, area of the Woredas ranged from 270 to about 1000 sq. kms with an average of 720 sq. Kms. Population of the Woredas also varied from 120 000 to about 500 000. A Woreda consists of several Peasant Associations (PAs), the number of which ranged from 33 to 70.

- A Peasant Association (PA) is the lowest administrative unit in rural Ethiopia and it has an area of about 800 hectares. A PA consists of 500 to 900 households, with a total population reaching as high as 6000 persons.

- A household consists of members of a family and other people permanently living in a house or houses. Members include parent(s), children (own or adopted), other relatives and hired labor. Most of the households in the study area are monogamous but there are also some polygamous households. In polygamous households, where the man has more than one wife, each wife, her children and other members live in a separate house within one compound with the other wife/wives. The land belongs to the husband and he gives each wife her share of land, which is managed by her and himself and the produce goes to her family. The husband shares meals with either of the wives, but residents of the different houses share food only on some occasions. Whenever necessary, the husband pulls the labor resources of all household members, particularly for activities such as harvesting. Female headed households accounted for 2 to 5 % of the total households in the PAs.

First, four Woredas were selected to represent possible local variations. In each Woreda, 2-4 Peasant Associations were selected on the basis of the two major variables that were believed to affect farm level species diversity. The variables are access to market and access to road. Names of the research PAs, their geographical locations and altitude are presented on table 2.1.

Within each PA 12 households were selected on the basis of their economic status. At each PA office, one can find list of all resident households classified as poor, medium and rich. The classification was made by the local administration based mainly on the criteria of land holding and livestock holding, but also on additional parameters such as the quality and quantity of coffee and enset plantation and involvement in off-farm activities. This classification was found suitable to select households for the present study. Accordingly, four households were selected at random from each category of economic group of farmers, making a total of 12 households per PA and 144 households for the whole study.

Table 2.1 Geographical location and altitudinal ranges of the research sites (PAs)

No	Site (PA)	Woreda	Locations of the PA offices		Altitude (meters)	Dominant soil types
			Latitude	Longitude		
1	Setamo	Dara	6°28'26.2" N	38°19'19.5" E	1840-2040	Eutric nitosols
2	Shoyicho	"	6°29'18.8" N	38°23'27.4" E	1840-1920	"
3	Qomato	"	6°29'54.9" N	38°23'32.9" E	1630-1700	"
4	Belesto	Aleta Wondo	6°36'03.5" N	38°24'33.1" E	1910-2000	Pellic vertisols
5	Lela Honcho	"	6°30'37.0" N	38°23'20.1" E	1740-1820	"
6	Tesso	"	6°32'24.9" N	38°19'16.6" E	1520-1710	Eutric nitosols
7	Sheyicha	"	6°37'08.8" N	38°25'06.6" E	1910-1970	Pellic vertisols
8	Ferro 1	Dale	6°44'58.5" N	38°28'17.9" E	1780-1890	Orthic acrisols
9	Ferro 2	"	6°44'25.9" N	38°29'52.3" E	1860-1940	"
10	Tula Aposto	"	6°45'59.4" N	38°22'39.1" E	1710-1740	Chromic luvisols
11	Chefasine	Awassa Zurya	6°55'58.6" N	38°29'48.8" E	1820-1870	Eutric fluvisols
12	Abela Tula	"	6°57'20.2" N	38°28'37.3" E	1830-1940	"

Note: The source for soil types is Soil map of Sidama Zone Planning and Economic Development Department (SZPEDD). The other data are collected in the present study.

2.3 Methods of data collection and analysis

Data were collected at four levels: Zone, Woreda, PA and household. At the first three levels, general information was collected on the biophysical and socioeconomic conditions. At Zone and Woreda levels, information was collected in three ways; a) from secondary sources b) through observations made during reconnaissance surveys of the zone and woredas and c) through interviews with professionals in the respective agricultural offices. At the PA level, data were collected through informal surveys from relevant sources such as key informants, peasant association leaders and development agents. The data generated at zone, woreda and PA levels were used to understand the overall setting of the research area.

At the household level, data were collected at two levels: farm and plot. Farm level data were collected using measurements, interviews and observations. Prior to the interviews, the farms were visited with the owner to make observations on the overall conditions of the farm. Often the farmers had one farm field that extends from the house. Some farmers have additional farm fields within a short distance in the same village, but the cropping pattern is often similar and there is a house in it. Data were collected from all farm fields of each household. During the visit, the layout of the farm was sketched and the different plots (units) of the farm identified, for the plot-level survey. Heads of the household, usually men, whenever possible with their wives, were involved in the interviews. Plot level data were collected from each unit of the farm. For each unit, the area was measured, and the different species of crops and trees identified and enumerated. Data were also collected on physical and socioeconomic characteristics of the farms such as altitude, slope, distance to markets and major roads, and household characteristics such as family size, labor force, age and educational status. Data were also collected on production levels (yield) of the different crops and livestock and the standing stock of trees.

Data were collected by the investigator and enumerators during the periods of 1999 to 2001. The enumerators were agricultural technicians who were employed from the respective localities for the purpose of data collection. The technicians had diploma or certificate level of training in agriculture and spoke Sidamigna, the local language. After recruitment, they were intensively trained on the methods and approaches of data collection.

The investigator visited each farm at least twice. In the first visit, the investigator, together with the owner of the farm and agricultural technician, visited the whole farm fields and then conducted the interview along with each enumerator. During the first visit, the area of the farms was measured and all species of cultivated crops and trees recorded. Sketches were also made of the types and locations of farm units to facilitate the plot-level data collection. The plot-level measurements often took several days, and they were undertaken by the enumerators. The investigator visited the farm for the second time to check on the accuracy of plot level data collection. The data generated from the farms were used for statistical analysis. The details on data collection and analysis are presented in the separate chapters dealing with the specific research questions.

CHAPTER 3

3. Diversity and composition of crops in the agroforestry homegardens of Southern Ethiopia

3.1 Introduction

Homegarden agroforestry systems in the tropics are known for their structural complexity and diversity in crop and other plant species (Michon *et* al., 1983; Fernandes and Nair, 1986). The cultivation of different crops is regarded as a strategy of farmers to diversify their subsistence and cash needs. Diversification also helps to stabilise yield or income in cases of incidences of disease and pests, and market price fluctuations. Moreover, the intimate association between the different herbaceous and woody components in these gardens is believed to enhance nutrient recycling and reduce hazards of leaching and soil erosion (Wiersum, 1982; Fernandes and Nair, 1992)

Homegardening is widely practised in the south and south-western highlands of Ethiopia. At the altitudes of 1500–2200 meters above sea level, where moisture and temperature conditions are more favourable for agriculture, the gardens are complex in species composition and structure. These gardens are characterised by a unique combination of two dominant perennial crops: enset and coffee. Enset (*Enset ventricosum* (Welw.) Cheesman) is a herbaceous multipurpose crop, and a staple food for about 10 million people in the region. Food is extracted from its pseudostem and corm, and its by-products as well as other parts serve different purpose, such as fibre, wrapping material, fodder, shade and soil fertility maintenance. Coffee (*Coffea arabica* L.) is mainlly used as cash crop, but also for household consumption. Other components of these multi-species agroecosystems include, chat (*Chata edulis*) which is a mild stimulant, root and tuber crops, fruits, vegetables, cereals, spices and other crops. Moreover, livestock are kept in the gardens and different tree species are grown to serve productive as well as protective functions.

The area of enset-coffee homegardens in Southern Ethiopia is not clearly known. BODEP (1996), has indicated that in the Southern Ethiopian Regional State alone, a total of 1.89 million hectares of land is cultivated. Out of these, the area of coffee and enset, and the crops often grown in association with them (such as fruits and vegetables, root and tuber crops, and pulses) is estimated at 576 000 hectares (BODEP, 1996). The homegardens constitute most of these areas.

These homegardens have been stable agricultural systems for centuries supporting populations that have densities of up to 600 persons per square kilometres (BODEP, 1996). The diversity of the systems, and the ability of enset to produce a relatively large amount of food per unit area (Admasu Tsegaye and Struik, 2001), could be the main factors that contributed to this stability. Coffee, which is predominantly produced in these smallholder agroforestry systems, is also the major foreign currency earner of the country. Obviously, these agroforestry systems ensure food security in the areas, play a significant role in the regional and national economies, and also contribute to environmental resilience. Despite these contributions, only few studies have been undertaken on the systems. Westphal (1975), in his study of agricultural systems in Ethiopia, has provided a detailed analysis and description of the systems along with lists of different crops grown in the region. The land use systems and components and their potentials for agroforestry were studied by a working group of the International Centre for Research in Agroforestry (ICRAF, 1989). Kippie (2002) has studied the landuse of Gedeo zone. Zemede Asfaw and Zerihun Woldu, (1997) have reported on crop associations of homegardens in Welayita and Gurage areas, two administrative zones in the region.

Still, little is known about these homegardens. The species richness and heterogeneity of crops in the systems as a whole, and at farm and plot levels is not known. This is particularly true to Sidama region where very little is known about the systems in general. Furthermore, in a predominantly small-holder subsistence farming system such as the study area, it is not only the number of species that is important but also the appropriate mix of different functional groups (commodity groups) of crops to meet balanced nutrition and cash needs of the households. Huang *et* al. (2002) have identified three categories of functional groups in agroforestry systems namely, ecological, conservational and livelihood functional groups. The latter, which they defined as "a set of species with similar impacts on the life-security processes of the local people", describes the functional groups presented in this study. Lastly, although enset and coffee are dominant throughout the systems, their area share and the share of other crops across the sites is not known.

The study presented in this chapter aims to characterize the diversity of crop species in the agroforestry homegardens of Sidama in Southern Ethiopia. More specifically, it attempts to answer the questions of, a) What is the crop species richness and the diversity of the homegardens?, b) What is the area share of the major crops?, c) What is the diversity in functional (commodity) groups of crops?, d) How is the diversity of crop species distributed at plot level? e) How does the area share of major crops compare across the sites? f) How does the yield of crops compare among the sites?

The homegardens of Sidama are composed of crops, different types of trees and livestock. This chapter deals only with the diversity of crops including tree crops such as fruits. Unlike the conditions where homegardens are considered as supplementary food production systems, the homegardens in the study area provide all the subsistence and cash needs of the households, and the farmers do not have additional land outside these systems. Therefore, the homegardens presented in this chapter should be regarded as equivalent to a farm system.

3.2 Materials and methods

The study area

The enset-coffee homegarden agroforestry systems are largely practised in the Southern Nations, Nationalities and Peoples' Regional State (SNNPRS) of Ethiopia. Sidama, one of the administrative zones in the region was selected to carry out the study due to its typical representativeness with respect to the production systems as well as the prevailing population pressure in the highlands.

Sidama is located within $5^0$45’-$6^0$45’ N latitude and 38^0-39^0 E longitude, and it covers a total area of 7672 square kilometres (SZPEDD, 1997). On the basis of the 1994 national census of Ethiopia (CSA, 1996), the current population of Sidama is estimated at 2.46 million people, out of which 93% is rural. Sidama zone constitutes diverse altitudinal zones ranging from 500 to 3500 meters a.s.l. However, the moist and humid, warm subtropical climatic zones that lie within altitudes of 1500-2500 are the most important in terms of their productivity as well as area coverage. These agroecological zones, which are locally known as *Gamoojje* or *Woyna Dega*, receive an annual rainfall of 1000 – 1600 mm, and enjoy a mean annual temperature of 15-20^0 C. In terms of size, they constitute 54% of the total area of Sidama. These areas are High Potential Perennial cropping areas where the enset-coffee homegarden agroforestry systems are dominant. Soil types prevailing in these systems include eutric nitosols, mollic andosols, orthic acrosols, and chromic luvisols (SZPEDD, 1997). The study was undertaken in 12 Peasant Associations selected from four Woredas where these agroforestry systems are practised.

Sampling

In order to have a fair representation of these systems across Sidama, stratified sampling procedures were followed at three levels: Woreda, Peasant Association (PA) and household. First, four Woredas were selected, and from each Woreda, 2 to 4 representative PAs (sites) were selected. Areas of the PAs ranged from 750 to 840 hectares and population density varied from 367 to 562 persons per square kilometre. Within each PA 12 households were selected on the basis of their economic status. Households in each PA are classified as poor, medium and rich on the basis of land holding, livestock holding, area and management intensity of coffee and enset crops and involvement in other income generating activities such as trading. From each category of economic group, four households were selected at random, making a total of 12 households per PA and 144 households for the whole study.

Methods of data collection

Data were collected from 144 sample households. In most cases each household has one piece of land with a house (houses), and the gardens surrounding it. Some farmers have an additional piece of land within short distances in the same PA, but the composition of species is often similar and there is a usually a house on it. Data were collected from all farms that are under the disposal of a household.

Data were collected at two levels; farm and unit. The homegardens often display a mosaic of patches or farm units which are distinct from one another because of the dominant crop grown on it. For instance, one can recognise a coffee unit where the dominant crop is coffee but intercropped with other crops, or a maize unit which appears more like a monoculture with few or no associated crops. The area allotted to the different unit types as well as their degree of intercropping varies considerably. Coffee and enset units, which are integrated with different crops and trees, form a multi-storey structure and they cover a very large proportion of these gardens. Because of their heavy dominance in relation to the small size of the farms, the integrated enset-coffee multistorey units are more evident and hence the term homegarden is used.

At farm level, the total area was measured and the different units were identified. For each unit, the area was measured, and the different species of crops identified. The population of annual crops and other widely grown small plants was estimated by making sample counts on systematically selected 1m x 1m quadrats and extrapolating it to the area it covers. For most perennial crops the total population was counted. The area share of each crop in the integrated units was calculated by considering the number of individuals of a particular crop in relation to its spacing and area of the unit. Data were also collected on average annual yields of the different crops.

Data analysis

To determine crop species diversity, species richness and species evenness of the homegardens (farms) were calculated. Species richness is the total number of crops on a farm. This index doesn't indicate the relative proportion or abundance of a particular species in the farm. Hence, indices that incorporate both richness and the evenness of abundance were required. Shannon index (Shannon and Wiener, 1949) and Evenness measure (E), which are commonly used tools for these purposes (Pielou, 1969: Magurran, 1988; Huston, 1995), were computed.

The Shannon diversity index (H') is high when the relative abundance of the different species in the sample is even, and is low when few species are more abundant than the others. It is based on the theory that when there is a large number of species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus the diversity. It is calculated using the formula, $H' = - \sum p_i \ln p_i$ (Magurran, 1988), where p_i is the proportion of crop area composed of species i.

An additional measure of diversity, which compares the observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated. The measure of Evenness (E) is the ratio of observed diversity to maximum diversity and it is calculated as, $E = H'/H_{max}, = H' /lnS$ (Magurran, 1988). E has values between 0 and 1.0, where 1.0 represents a situation in which all species are equally abundant.

Richness and diversity of functional groups of crops were also calculated using Shannon and Evenness indices. The values obtained from the above calculations were analysed statistically to test for significance of differences.

The above indices, which are generally referred as alpha diversity, indicate richness and evenness of species within a locality, but they do not indicate the identity of the species and where it occurs. Hence, variation in composition of species among the different PAs was determined by computing Beta diversity. Beta diversity (β) is usually expressed in terms of a similarity index between different habitats in the same geographical area (Huston, 1995). It is calculated using the formula, $\beta = 1 - C_j$, where C_j is Jaccard's similarity index (Magurran, 1988)

$$C_j = j/(a+b - j)$$

where j = the number of species shared by any two sites a and b,
a = the number of species in site a, and
b = the number of species in site b

On the basis of the variation in area share of major crop species across the sites, different prototypes of the enset-coffee homegarden agroforestry systems were identified.

The monetary value of the crops grown in the different prototypes was calculated by multiplying the annual yield by the average marketprice.

3.3. Results

3.3.1 Richness and evenness of crop species

Richness of crop species

A total number of 78 cultivated crop species were recorded for the study area. Among these, 13 species occurred in 50% of the farms with crops such as enset, coffee and maize being common in all farms. On the other hand, 34 species were rare, occurring in less than 5% of the farms. Figure 3.1 shows the frequency of occurrence of the species with lists of their names. The average number of crop species per farm was 16 with values ranging from 7 to 26. In addition to enset and coffee, which are the key species in the system, food crops such as maize, beans and cabbage, that contribute to the daily diet of the farm family, are also common in almost all farms. Other crops that are widely grown in the area include avocado, banana, pumpkin, rhamnus and chat.

The number of crop species varied across the woredas and sites (PAs). At woreda level, Aleta Wondo had the highest number of crops (64) accounting for 82% of the total number of species in the samples (Table 3.1). This is not surprising because it also had the highest sample size. The woreda-level species richness did not correspond with farm level results. The mean number of crop species per farm in Aleta Wondo (15.5) was lower than that of Dara and Dale, indicating that each farm represented only 24% of the total pool of crop species available in the woreda. This also suggests that farms in Aleta Wondo are more different from each other in terms of species composition. Farm level species richness was generally higher in Dale and Dara woredas, but the variability in species composition across farms is lower as compared to Aleta Wondo. Awassa Zurya woreda, with the lowest sample size had the lowest total number of 33 crop species. Obviously, the low sample size could affect the total number of species at woreda level, but the average number of species at farm level was also the lowest.

At PA level, the highest number of species (48) was recorded at Lela Honcho while the lowest (26) was in Abela Tula (Table 3.2), and this corresponded with woreda level results. Lela Honcho represented 75% and 62% of the crop species grown in Aleta Wondo woreda and the whole study area, respectively. On the other hand, the PA level richness of Lela Honcho did not correspond with farm level results. The average number of 15.8 crop species per farm indicated that each farm represented only 33% of the species in the PA. Farm level species richness was highest at Tula-Aposto PA of Dale woreda where the mean of 20.3 species represented 47% of the total crops in the PA. In general, farms in Dale and Dara woredas are rich in species and they represented an average of 40% of the total species grown in their respective PAs.

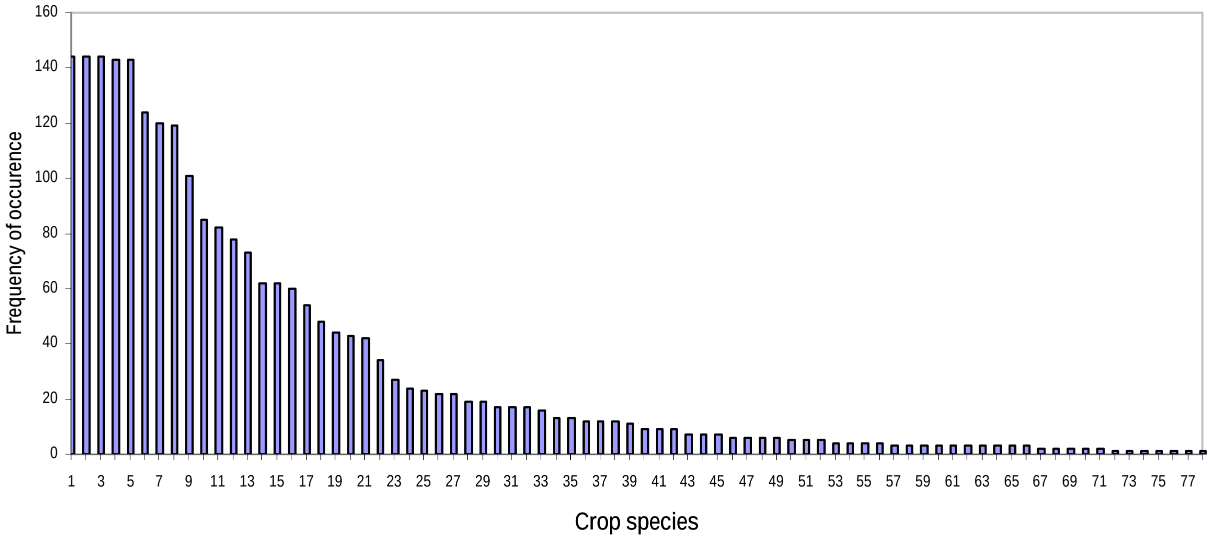


Figure 3.1 Occurrence frequency of crop species across the farms (n=144)

Legend:

Nr.	Scientific name	Nr.	Scientific name	Nr.	Scientific name
1	*Enset ventricosum*	27	*Prunus persica*	53	*Rosmarinus officinalis*
2	*Coffea arabica*	28	*Carica papaya*	54	*Vicia faba*
3	*Zea mays*	29	*Passiflora edulis*	55	*Ocimum basilicum*
4	*Brassica integrifolia*	30	*Ocimum gratissimum*	56	*Lippia adonensis*
5	*Phaseolus vulgaris*	31	*Capsicum annuum*	57	*Carthamus tinctorius*
6	*Persea americana*	32	*Lippia adoensis*	58	*Daucus carota*
7	*Musa paradisiaca*	33	*Pennisetum purpureum*	59	*Latuca saliva*
8	*Cucurbita pepo*	34	*Annona reticulata*	60	*Allium porrum*
9	*Rhamnus prinoides*	35	*Solanum villosum*	61	*Pisum sativum*
10	*Dioscorea alata*	36	*Arachis hypogea*	62	*Cajanus cajan*
11	*Chata edulis*	37	*Manihot esculenta*	63	*Hoedeum vulgare*
12	*Saccharum officinarum*	38	*Mangifera indica*	64	*Triticum sativum*
13	*Colocasia esculenta*	39	*Nicotiana tobacum*	65	*Foeniculum vulgare*
14	*Capsicum frutescens*	40	*Cyphomandra betacea*	66	*Gossypium herbaceum*
15	*Psidium guajava*	41	*Solanum tuberosum*	67	*Chloris gayana*
16	*Ricinus communis*	42	*Eragrostis tef*	68	*Allium sativum*
17	*Ipomoea batatas*	43	*Aframomum korarima*	69	*Punica granatum*
18	*Citrus sinensis*	44	*Beta vulgaris*	70	*Otostegia integrrifolia*
19	*Brassica oleracea*	45	*Fragaria vesca*	71	*Cymbopogon citratus*
20	*Sorghum bicolor*	46	*Lagenaria siceraria*	72	*Dioscoria bulbifera*
21	*Phaseolus lunatus*	47	*Citrus aurantifolia*	73	*Piper nigrum*
22	*Casimora edulis*	48	*Plectranthus edulis*	74	*Nigella sativa*
23	*Ananas comosus*	49	*Agava sisalana*	75	*Linum unisatissimum*
24	*Brassica carinata*	50	*Allium cepa*	76	*Artemisia absinthium*
25	*Ruta chalepensis*	51	*Brassica oleracea var. capitata*	77	*Desmodium unicinatum*
26	*Lycopersicon esculentum*	52	*Zingiber officinale*	78	*Sorghum dochna*

Table 3.1 Total and average number of crops in the research woredas (n =144).

Woreda	Nr. of farms	Total nr. of crop species	Mean nr. of crop species per farm	Standard deviation
Dale	36	57	17.9 [a]	3.7
Dara	36	56	17.5 [a]	3.7
Aleta Wondo	48	64	15.5 [b]	3.6
Awassa Zurya	24	33	12.3 [c]	2.2
Mean		*53*	*16.0*	*3.9*
F-test (P)			<0.001	

Table 3.2 Total and average number of crop species, mean values of the Shannon (H') and the Evenness (E) indices at the research sites (PAs).

Site (PA) (n/PA=12)	Woreda	Number of crop species			Shannon index	Evenness index
		Total	Mean	SD	*H'*	*E*
Setamo	Dara	43	17.5 [ab]	3.2	1.50 [bc]	0.53 [bc]
Shoyicho	"	44	17.7 [ab]	4.1	1.47 [bcd]	0.52 [bc]
Qomato	"	43	17.3 [b]	1.2	1.52 [b]	0.54 [b]
Belesto	Aleta Wondo	47	15.4 [bc]	3.7	1.32 [de]	0.49 [bc]
Lela Honcho	"	48	15.8 [bc]	4.5	1.21 [e]	0.45 [c]
Tesso	"	38	15.0 [bc]	3.1	1.75 [a]	0.65 [a]
Sheyicha	"	43	15.6 [bc]	3.8	1.23 [e]	0.45 [c]
Ferro 1	Dale	38	17.7 [ab]	2.5	1.53 [b]	0.54 [b]
Ferro 2	"	40	15.6 [bc]	3.0	1.34 [cde]	0.49 [bc]
Tula Aposto	"	43	20.3 [a]	3.5	1.64 [ab]	0.55 [b]
Chefasine	Awassa Zurya	27	13.0 [cd]	2.7	1.57 [b]	0.62 [a]
Abela Tula	"	26	11.7 [d]	2.1	1.27 [e]	0.53 [bc]
Mean		*40*	*16.0*	*3.9*	*1.45*	*0.53*
F-test (P)			<0.01		<0.001	<0.001

Note: Means followed by different letters indicate significant differences at P < 0.05, according to Duncan's Multiple Range Test.

Diversity of crops

Diversity of crop species differed significantly across the PAs (Table 3.2). Species evenness was highest for farms in Tesso PA, where expanding new cash crops such as pineapple and chat have reduced the proportion of enset and coffee. Here, the mean values of Evenness (E) as well as Shannon's index were the highest. The mean Evenness value of 0.65 for farms in this PA indicated that evenness in abundance of the species is 65% of what would have been under uniform or even distribution. The least uniform composition of crop species with evenness value of 0.45 was calculated for farms in Lela Honcho and Sheyicha PAs where coffee and enset alone shared about 80% of the crop areas. On the whole, the population of crop species had a relative evenness of 53%.

The evenness values are not high enough to justify uniformity in composition of crop species. This is expected because in agroecosytems not all crops are required in equal volume. For instance, staple food crops that are consumed in large quantities necessarily need a large area of production, whereas crops such as spices that are required in small quantities are grown in smaller spaces (Figure 3.2). Enset and coffee, which are the key species in the system, accounted for about 63% of the total area of crop production at the research sites. Coffee, which is the main cash crop[1] in the region, covers about 36.6% of the areas under crop. Together with chat, pineapple, sugarcane and fruits, the cash crops accounted for 46.6% of the cropping areas while the remaining 53.4% is covered by subsistence crops. This pattern is more or less similar across the woredas except for Awassa Zurya, where a suitable market infrastructure for chat and proximity to the regional capital, Awassa, has affected the composition. In Awassa Zurya woreda, the share of coffee has reduced to 13% and the proportion of maize and chat has increased up to 35%. In general, the dominance of few crop species has contributed to a low evenness value.

Genetic variation in crop species adds to another form of diversity in these systems. This is particularly true to enset and coffee. A total of 42 landraces of enset were recorded in these homegardens out of which an average of 6 was grown in each homegarden. Likewise, 26 cultivars of coffee were identified, out of which 15 were local landraces and 11 were improved, Coffee Berry Disease resistant varieties. An average of three coffee cultivars is grown in each farm.

The diversity and the space taken by crops of the crops vary spatially and temporally. Spatial variation refers to vertical stratification of the integrated enset-coffee multistorey units. Four distinct layers of crops are observed in these systems. Vegetables, spices, beans, root and tuber crops occupy the lowermost strata of up to 1.5 meters. Coffee, enset, maize, chat, sugarcane, some fruit trees such as banana and papaya, etc. occupy the layer between 1.5 and 5 meters. Fruit trees such as avocado and white sapote, some shrubs and pollarded shade trees dominate the third layer of 5-12 meters. The fourth layer of above 12 meters, which could sometimes extend up to 35 meters, is dominated by timber producing shade trees. The lowermost stratum is the richest in species (64%) while the second one is the densest because of the heavy dominance of enset and coffee.

Temporal variation in richness and composition of species are other characteristics of these agroecosystems. The key components of these homegardens are perennial crops, enset and coffee with a life cycle of 6-8 and 24-30 years, respectively. In addition to these, other perennials such as chat and fruit trees are also widely grown. While such perennials and most other components are present throughout the year, herbaceous crops such as cereals and vegetables are grown only during the rainy period of 6 to 9 months. Hence, the diversity and composition of crops increases during the growing period and declines seasonally when the herbaceous annuals are harvested.

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[1] In these farming systems, the distinction between cash crop and subsistence crop is not clear. Coffee, which is a cash crop, is also consumed at home. On the other hand, the staple food crops such as Qocho (the product of enset) and maize are also marketed whenever it is necessary. Hence, the categories, 'cash crop' and 'subsistence crop' should be understood as indicators of whether the majority of the produce is sold or consumed.

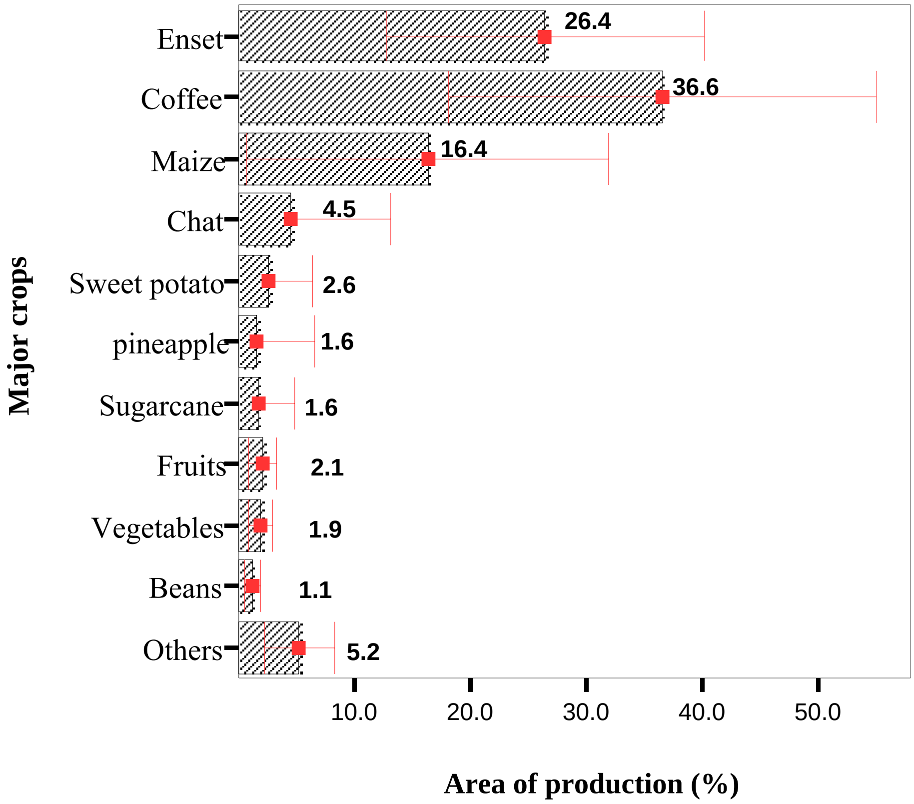

Figure 3.2 Mean area share of the major crops in the research sites. Error Bars show Mean +/- 1.0 SD.

3.3.2 Crop diversity at plot level

The results so far showed crop diversity at farm level. However, crop diversity differs also within a farm and within farm units or plots. In these homegardens, one can observe a mosaic of different plots/units that are distinct from one another by the type of the dominant crop grown (Figure 1.2). Such allocation is often based on considerations of management suitability and characteristics of specific locations. For instance, enset, which requires heavy manuring, is often grown near houses to facilitate transportation of manure. Marshy areas are planted with sugarcane or eucalypts, and steep slopes are planted with perennial crops or trees. It is also common to see different units of the same crop in one farm. This is particularly true for enset and coffee plantations belonging to different age classes.

The farm units are not equally rich in species (Figure 3.3). The enset and coffee units with a mean of 13.6 and 12.8 associated crop species respectively, are the ones that contribute to high species richness of the farms. The complexity and multistorey structure of the farms is also largely manifested in these two unit types. The two crops are often found associated in one unit although the unit could be named by the dominant one. The number of crop species associated with either of the two units reaches as high as 25 in some farms. There are some cases when enset or coffee units are less diverse in species. a) Enset plants younger than 3 years are sometimes grown in very high densities that hinder accommodation with other crops. The maintenance of high density of young enset is meant to generate sufficient planting material and biomass for fodder. Moreover, the high ground cover provided by the dense enset is believed to improve soil organic matter through decomposition of dying lower leaves. Once portions of these plants are thinned for transplanting or other purposes, there will be space to accommodate other crops (b) Coffee plantations of improved cultivars, are often grown in high densities of more than 3000 plants per hectare accommodating few herbaceous crops.

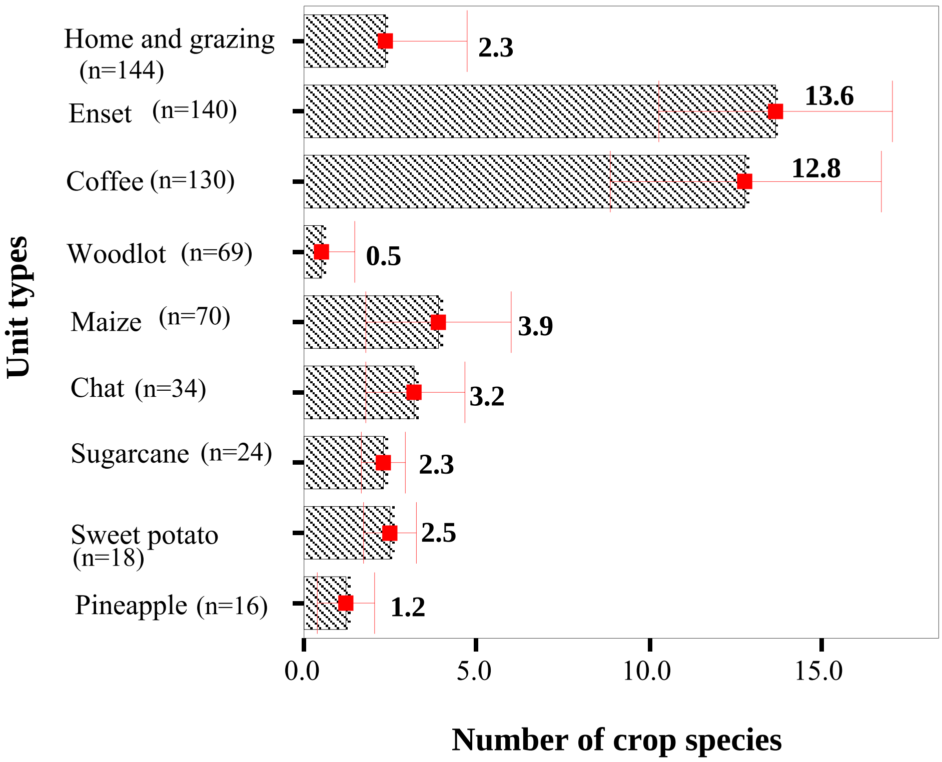

Figure 3.3 Mean number of associated crop species with the different farm unit types. Error Bars show Mean +/- 1.0 SD.

3.3.3 Richness and evenness in functional groups of crops

A total of 10 functional groups of crops were recognised each represented by 3 to 15 species of crops (Appendix 3.1), and an average of 8.1 groups were found in each farm. Out of the average number of 16 crops per farm, fruit crops contributed 23%, followed by root and tubers (16%) and vegetables (14%) (Figure 3.4). It should be noted that this proportion shows the number of crop species in the commodity groups and it doesn't have any relation with their abundance or area coverage in the farms. For instance, fruit crops constituted 23% the average number of crop species, but they covered only 2% of the farm areas. On the other hand, coffee, only one of the stimulant crops represented 33% of the farm areas.

The minimum average number of functional or commodity groups of crops per site was 7.3 and the maximum was 8.6 (Table 3.3). This shows that most of the groups are represented in the farms although the number of species in each group could be low. Shannon and Evenness indices also showed similar results, with mean values of 1.95 and 0.71, respectively.

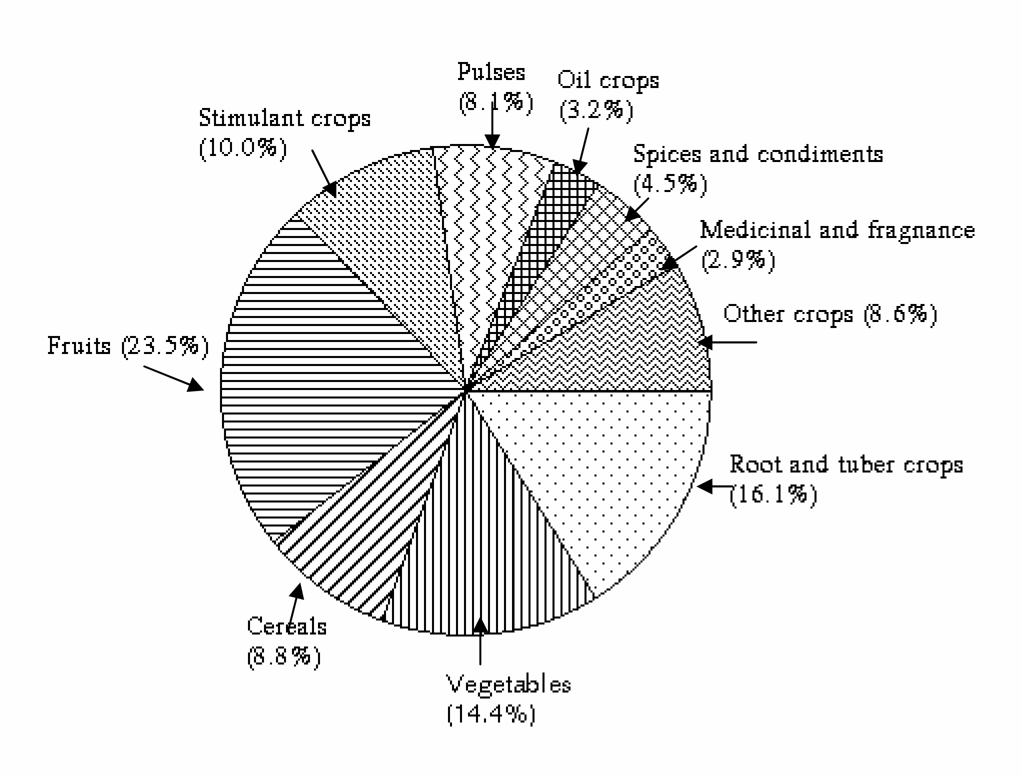

Figure 3.4 Mean proportion of functional groups of crops per farm

3.3.4 Similarity of sites in composition of crop species

From the discussions made so far it can be concluded that the enset-coffee agroforestry systems of Sidama have basic species assemblages such as enset, coffee, maize, cabbage, beans, avocado, banana, etc. which are common among the farms but differences exist in the distribution of less-common or rare species. Beta diversity (β) was computed to identify similarities or differences of the sites with respect to composition of crop species (Table 3.4).

Table 3.3 Richness and diversity of functional groups of crops for all sites (12 farms per site).

Site (PA)	**Mean number of commodity groups**	**SD**	**Shannon index (*H'*)**	**SD**	**Evenness (*E*)**	**SD**
Setamo	8.58 [a]	0.90	2.00 [a]	0.09	0.71 [bc]	0.06
Shoyicho	8.08 [abc]	1.00	1.91 [a]	0.09	0.67 [cd]	0.03
Qomato	7.67 [bc]	1.15	1.79 [b]	0.22	0.65 [d]	0.11
Belesto	8.25 [ab]	0.97	1.95 [a]	0.11	0.73 [ab]	0.05
Lela Honcho	7.92 [abc]	0.90	1.91 [a]	0.10	0.70 [bc]	0.06
Tesso	8.08 [abc]	0.67	1.97 [a]	0.11	0.74 [ab]	0.06
Sheyicha	8.25 [ab]	1.14	1.98 [a]	0.15	0.73 [ab]	0.05
Ferro 1	8.58 [a]	1.08	2.01 [a]	0.14	0.71 [bc]	0.04
Ferro 2	8.17 [abc]	0.83	1.98 [a]	0.09	0.73 [ab]	0.05
Tula Aposto	8.58 [a]	0.79	1.99 [a]	0.08	0.67 [cd]	0.04
Chefasine	8.00 [abc]	0.60	1.97 [a]	0.09	0.76 [a]	0.05
Abela Tula	7.33 [c]	0.98	1.91 [a]	0.14	0.78 [a]	0.06
Mean	*8.13*	*0.97*	*1.95*	*0.13*	*0.71*	*0.07*
F-test (P)	<0.05		<0.01		<0.001	

Table 3.4 Beta diversity: dissimilarity values for crop species composition of the sites

Sites (PAs)	**Setamo**	**Shoyicho**	**Qomato**	**Belesto**	**Lela Honcho**	**Tesso**	**Sheyicha**	**Ferro1**	**Ferro2**	**Tula Aposto**	**Chefa-sine**	**Abela Tula**
Setamo	-	0.29	0.35	0.30	0.37	0.35	0.35	0.35	0.37	0.31	0.60	0.50
Shoyicho		-	0.33	0.37	0.44	0.39	0.39	0.48	0.42	0.42	0.61	0.57
Qomato			-	0.42	0.48	0.44	0.46	0.47	0.43	0.41	0.57	0.50
Belesto				-	0.39	0.37	0.27	0.43	0.33	0.36	0.55	0.54
Lela Honcho					-	0.41	0.43	0.46	0.51	0.46	0.58	0.58
Tesso						-	0.35	0.45	0.44	0.38	0.59	0.51
Sheyicha							-	0.38	0.37	0.38	0.57	0.53
Ferro 1								-	0.37	0.44	0.52	0.48
Ferro 2									-	0.43	0.54	0.53
Tula-Aposto										-	0.54	0.43
Chefasine											-	0.39
Abela Tula												-

Note: The value of Beta diversity ranges from 0 to 1. A value of 0 means the two sites are similar in composition of species, and 1 is when no species is shared among two sites.

There are dissimilarities in crop species composition among the PAs. The closely located Belesto and Sheyicha PAs from Aleta Wondo woreda had the least dissimilarities of only 27%, which means that they shared 73% of the crop species. On the other hand, Shoyicho and Chefasine that are located about 65 kilometers apart and in different woredas were 61% dissimilar in species composition. Chefasine and Abela-Tula in Awassa Zurya woreda, are generally more different than the rest of the PAs often sharing with others only less than 50% of crop species. Geographical distance partly explains the differences among the sites with respect to composition of crop species (Figure 3.5).

In addition to the differences in composition of crop species, area share of the major crops also differs across the sites. At some sites the share of enset and coffee is low. This difference in the relative importance of the crops at each site is largely influenced by marketing opportunities and physical factors such as altitude. On the basis of differences in the area share of dominant crops four prototypes of the enset-coffee agroforestry homegardens can be distinguished (Table 3.5). The prototypes and their basic characteristics are presented below.

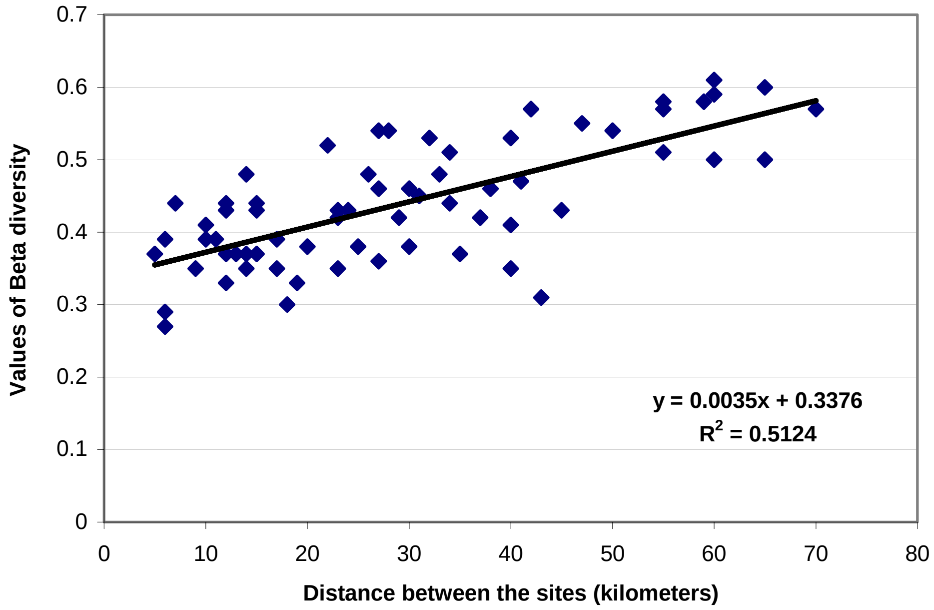

Figure 3.5 The relationship between distance of the sites and their Beta Diversity values.

3.3.5 Prototypes of enset-coffee homegardens

1. Enset-Coffee-Maize sub-system

This prototype is found in seven PAs, largely at altitudes of 1800 to 2000 meters. Average land holding is 1.5 hectares and there is poor access to major roads. Here, coffee and enset constitute 70-80% of the crop areas, maize covers 7-16%, and altogether the three crops have a share of 80-90% of the areas under crop. Coffee is almost entirely the sole cash crop and it covers more than 40% of the crop areas. Enset makes the bulk of the human diet and it is supplemented by maize. The major difference from the other prototypes is that new cash and food crops such as chat, pineapple and sweet potato are not widely grown, but fruits, vegetable and other crops are common. Species richness of this prototype is generally high. The mean number of crop species is 16.5, while evenness (E) value was 0.50. The number of commodity groups of crops (8.3) as well as evenness of their distribution (0.71) was high (Table 3.6). These farms are located away from the major roads and the landuse did not change much over time. Thus, they are more or less original type systems. They are predominantly complex multi-storey agroforestry systems, where integrated use of local resources provides various ecological and economic benefits. The characteristics mentioned above indicate that these prototypes are ecologically stable.

Table 3.5 Prototypes of the enset-coffee homegarden systems and area share of major crops at the representative sites.

Site (PA)	Woreda	Enset	Coffee	Maize	Chat	Sweet potato	Pineapple	Others
Prototype 1. Enset-Coffee-Maize sub-system								
Setamo	Dara	32.1	42.0	10.1	0.7	1.3	1.1	12.7
Shoyicho	"	20.9	48.8	15.7	0.2	0.5	0.4	13.5
Lela Honco	Aleta Wondo	33.1	47.0	8.5	0.1	0	0.1	11.2
Belesto	"	35.3	42.4	9.7	0.1	0.9	0.2	11.4
Sheyicha	"	26.2	55.4	7.4	0.6	0	0	10.4
Ferro 1	Dale	24.2	47.8	8.7	1.3	4.2	0	13.8
Ferro 2	"	31.9	39.8	13.5	1.0	1.3	0	12.5
	Mean	**29.1**	**46.5**	**10.5**	**0.6**	**1.2**	**0.3**	**12.2**
Prototype 2. Enset-Coffee-Maize-Sweet potato sub-system								
Tula-Aposto	Dale	**17.2**	**27.2**	**33.0**	**0.8**	**10.6**	**0**	**11.2**
Prototype 3. Enset-Coffee-Maize-Chat sub-system								
Chefasine	Awasa Zurya	26.4	14.5	20.8	27.1	1.7	0	9.5
Abela Tula	"	23.2	12.8	42.4	12.5	1.1	0	8.0
	Mean	**24.8**	**13.7**	**31.6**	**19.8**	**1.4**	**0.0**	**8.7**
Prototype 4. Enset-Coffee-Maize-Pineapple and Chat sub-system								
Qomato	Dara	23.8	33.3	14.4	3.4	5.2	4.2	15.7
Tesso	Aleta Wondo	23.1	28.8	10.0	9.6	5.3	12.7	10.5
	Mean	**23.5**	**31.1**	**12.2**	**6.5**	**5.3**	**8.5**	**13.1**
Overall mean		**26.4**	**36.6**	**16.4**	**4.5**	**2.6**	**1.6**	**11.9**

Note:

The values indicate percentage area coverage of the different crops. The percentage is calculated by considering only crop areas. Residential and grazing areas and separate woodlots are not included in the calculation

Table 3.6 Richness in crop species and functional groups of crops at the different prototypes of the enset-coffee homegardens.

Prototype	Crop species		Functional groups of crops	
	Mean nr. per farm	Evenness (E)	Mean nr. per farm	Evenness (E)
1. Enset-Coffee-Maize (n=84)	16.5	0.50	8.26	0.71
2. Enset-Coffee-Maize-Sweet potato (n=12)	20.3	0.55	8.58	0.67
3. Enset-Coffee-Maize-Chat (n=24)	12.3	0.57	7.67	0.77
4. Enset-Coffee-Maize-Chat-Pineapple (n=24)	16.1	0.60	7.88	0.70
Mean	**16.0**	**0.53**	**8.13**	**0.71**

2. *Enset-Coffee-Maize-Sweet potato sub-system*

This sub-system is found in one PA with lower altitudes of 1710 to 1740 m.a.s.l. The average land holding is 0.98 ha. It has access to major road. Chat, which is an important cash crop in road-access sites is not grown here because the soil is unsuitable. However, some farmers sell eucalyptus posts and fuelwood, but the system is generally subsistence based. The area of enset is the lowest (17%), and thus more area is brought under maize (33%) and sweet potato (11%) production. The lower altitude of the sites has created favourable condition for expansion of sweet potato. Coffee, which is the only cash crop component of the system had a share of 27% which is less than the overall average of the sites, and the remaining 73% is allotted to food crops. Crop species richness is the highest with a mean of 20.3 crops per farm and evenness value was 0.55. The number of commodity groups is the highest (8.6) but with lower evenness (0.67).

3. *Enset-Coffee-Maize-Chat sub-system*

This prototype is found in two PAs. Altitude of the sites is above 1800 m.a.s.l. Average land holding is 0.89 hectares and there is access to major roads. Here, the share of enset (25%) is almost equal to the average of all sites. However, the share of coffee declines to less than 15% as compared to the overall average of 37%. On the other hand, the share of maize and chat increased to 32 and 20%, respectively by far exceeding the respective overall average values of 16 and 5% for the two crops. The area of chat production exceeds or equals that of coffee indicating that chat is the major cash crop in these sites. The evolvement of chat as an important cash crop in these sites is associated with road access and also the presence of a big chat market in the locality. A larger proportion of maize is meant to safeguard against food insecurity caused by lower yield of enset. Poor farmers in these sites allocate more than 40% of their cropland to maize, but about 20% to enset. This indicates the increasing dependence on maize for their subsistence. The pattern of land allocation to the two cash crops is also different. Poor and medium farmers, who are often faced with cash shortage, are more dependent on chat as a cash crop. However, the rich ones seem to maintain a balance between the chat and coffee area so as to diversify their income and avoid any risk associated with any one of the two crops. Species richness of this sub-system is the lowest with a mean of 12.3 crop species per farm. Evenness (E) in abundance of crop species (0.57) is slightly higher than the previous prototype because of the increased share of chat. The number of functional groups is also the lowest (7.7), but with high evenness (E=0.77).

4. *Enset-Coffee-Maize-Pineapple-Chat sub-systems*

This prototype occurs in two PAs, which have lower altitudes of 1520 to 1730 meters a.s.l., and a relatively warmer temperature. Annual rainfall is 1000-1200 mm (SZPEDD, 1997), but available moisture could be low due to high evapotranspiration rates. Average farm size is 1.76 hectares. It has access to major roads. The presence of a highway coupled with the relatively lower available moisture have led to the development of land use systems where the share of new cash and subsistence crops has increased compared to prototype 1. Here coffee and enset have a share of 50-60%, and maize has 10-14%. The three crops altogether cover 60-70% of the farm areas, leaving 30-40% to other crops. The combination of pineapple, sweet potato and chat with a share of about 13 to 28% of the crop areas makes these sites different from the others.

The area of enset is lower and this could lead to shortage of food. Hence, growing more of maize and sweet potato compensates the deficiency. Likewise, the cash crops, pineapple and chat compensate for the lower share of coffee. The lower altitude meets the ecological requirements of pineapple. Moreover, the relatively large land holdings and the presence of road access for marketing, have made it economically attractive to grow pineapple as an important cash crop. Species richness was high with a mean value of 16.1 crops per farm, and evenness (E) was the highest (0.60). This is due to the presence of six well represented dominant crops, instead of three or four, which was the case for the other types. Together, the six crop species share a total of 86% of the crop areas. However, the mean number of functional groups as well as its evenness is slightly lower than the overall average.

3.3.6 Crop yield of the different prototypes of the enset-coffee systems

The yield of the crops per unit area varied with prototypes. In general, most crops had higher yields in the enset-coffee-maize prototypes. Yield also varied among farms within a site mainly due to soil fertility management conditions. The absence of cattle in the farm, and the consequent lack of animal manure for soil fertility maintenance, is a very important factor that affected yield of crops, especially that of enset.

In spite of the fact that the yield of crops is higher in the enset-coffee-maize prototypes, the monetary value of crops is higher for prototypes that have introduced new cash crops (Table 3.7). Accordingly, the enset-coffee-maize-chat and the enset-coffee-maize-chat-pineapple prototypes had crop outputs worth Birr 6802.00 and 6809.00 per hectare, respectively as compared to Birr 5084.00 for the enset-coffee-maize prototypes (Figure 3.6). The subsistence based enset-coffee-maize-sweet potato prototype has the lowest crop outputs of Birr 4382.00 per hectare, since the only cash crop, coffee is produced in small quantities. Root and tuber crops such as sweet potato and yam have a very high productivity per unit area and they fetch high values. However, they couldn’t develop into cash crops because; a) they are bulky for transportation, b) they require more labor, and c) they have lower demand. Thus farmers grow them mainly for home consumption.

Table 3.7 Mean area, and annual yield and monetary value of major crops produced per farm in the different prototypes of the enset - coffee homegarden systems

PROTOTYPES	Para-meters	CROPS													
		Enset	Coffee	Maize	Chat	Sweet potato	Pine-apple	Sugar -cane	Fruits	Vege-tables	Beans	Other cereals	Root & tubers	Others	Total
Enset-Coffee-Maize (n=84)	Area (%)	23.7	50.5	10.9	0.7	1.5	0.06	1.5	2	1.9	1.3	1.2	2	2.8	100.0
	Area (ha)	0.36	0.82	0.16	0.01	0.02	0.001	0.03	0.03	0.02	0.01	0.01	0.03	0.04	1.54
	Yield (kg)	4395	592	289	129	679	12	3078	1210	733	22	17	1946	-	11871
	Value (birr)	2637	2962	231	258	237	12	369	484	183	29	15	486	167	8072
Enset-Coffee-Maize-Sweet potato (n=12)	Area (%)	16.8	26.8	34.6	1	9.3	0	0.4	2.9	1.4	1.3	0.7	1.5	3.4	100
	Area (ha)	0.18	0.24	0.34	0.01	0.09	0	0.01	0.03	0.01	0.01	0.01	0.02	0.03	0.98
	Yield (kg)	1821	155	564	148	2210	0	1127	1242	410	16	21	895	-	8330
	Value (birr)	1093	775	451	297	774	0	135	497	103	22	19	224	130	4517
Enset-Coffee-Maize-Chat (n=24)	Area (%)	24.2	13.2	31.0	18.1	0.5	0	0.7	1.8	2.2	1.3	0	1.2	3.0	100
	Area (ha)	0.31	0.19	0.33	0.20	0.005	0	.007	0.02	0.02	0.01	0	0.01	0.03	0.89
	Yield (kg)	3012	117	538	1989	103	0	528	742	678	15	0	939	-	8033
	Value (birr)	1807	585	430	3979	36	0	63	297	170	19	0	235	132	7753
Enset-Coffee-Maize-Chat-Pineapple (n=24)	Area (%)	23	28.7	10.8	10	3.6	11.5	1.4	2	1.8	0.8	2.5	1.2	2.3	100
	Area (ha)	0.32	0.51	0.21	0.14	0.06	0.31	0.04	0.04	0.04	0.01	0.02	0.02	0.04	1.76
	Yield (kg)	2806	305	350	1425	1375	3770	4250	1146	853	18	28	1145	-	16075
	Value (birr)	1683	1528	280	2850	481	3603	510	459	213	24	25	286	177	12118
Mean	Area (%)	22.8	33.3	20.9	7.0	2.6	1.9	1.2	2.0	1.9	1.2	1.0	1.6	2.9	100
	Area (ha)	0.31	0.51	0.24	0.08	0.03	0.05	0.02	0.03	0.02	0.01	0.01	0.02	0.04	1.36
	Yield (kg)	3405	353	408	848	833	634	2238	1071	689	19	14	1393	-	11318
	Value (birr)	2043	1765	327	1697	291	606	269	429	172	25	13	348	153	8051

Note: a) The use of external inputs in the systems is generally low, but some farmers included in agricultural extension programs use chemical fertilizers and improved seeds only for maize. Thus, the yield of all crops including maize is calculated on the basis of zero external input use.

b) *Birr* is the Ethiopian legal currency. One birr = ± 0.10 Euro

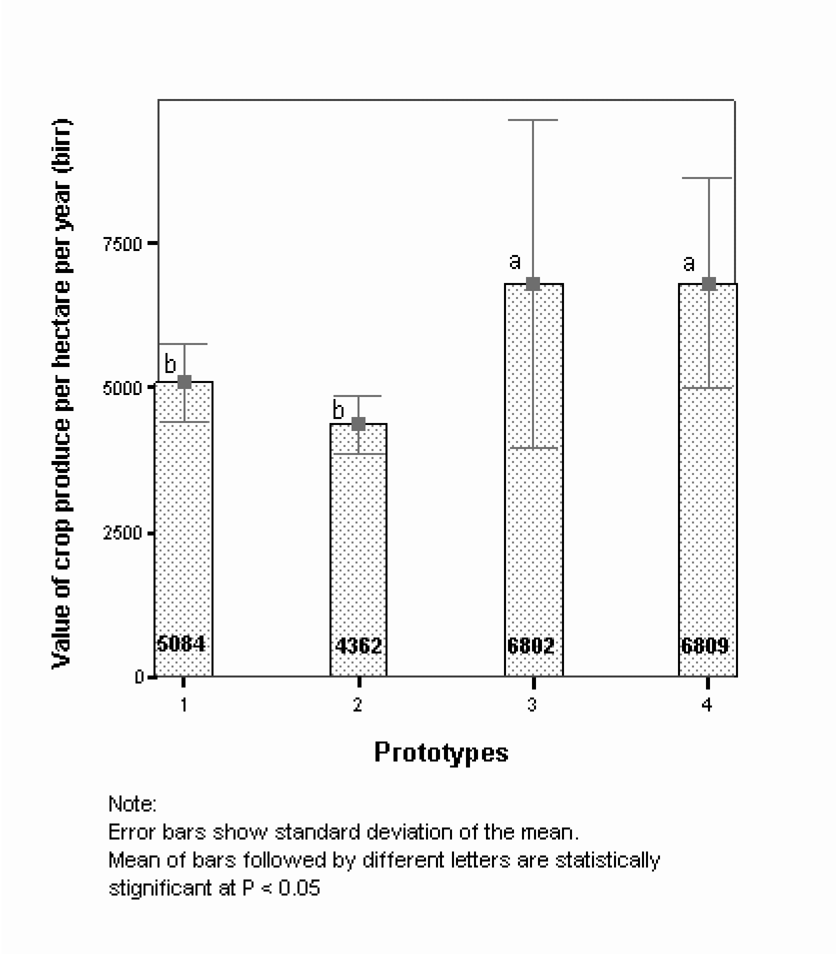

Figure 3.6 Mean value ha^{-1} yr^{-1} of all crops produced in the different prototypes of the enset-coffee homegarden systems.

3.4 Discussion

Richness and evenness in crop species

The enset-coffee homegardens of Sidama are generally rich in crop species where a total of 78 cultivated crops are grown with an average of 16 crops per farm. Most reports of homegardens indicate the total diversity of plant species including crops, trees, ornamentals, creepers and other herbs. Thus, the figure is often high. For instance, Mendez *et* al. (2001) reported the occurrence of 324 plant species in the homegardens of Nicaragua. Out of these, 180 (56%) were ornamentals, 40 were fruit trees and only 12 were food crops and spices. Likewise, in the widely known homegardens of Java, Jensen (1993) found 60 plant species in only one garden of 0.13 hectare, of which 21 were ornamentals. In general, homegardens in the humid lowland tropical areas such as the ones mentioned above have a high plant species diversity because rainfall and temperature conditions are more favourable than in the tropical highlands. But, the very high figures are also due to the fact that all plant species, sometimes including weeds, are considered.

In the present study, only deliberately planted and cultivated crop plants are considered. Ornamentals, weeds as well as trees and shrubs are not included. Out of the total number of 78 crop species, 84% were food crops and spices. An additional 120 tree species were recorded in these homegardens (Chapter 5), but they are not treated in this chapter. Therefore, the homegardens of Sidama with such a high proportion of food crops are species rich agroecosystems. The result obtained here is slightly higher than what was reported for the Chagga homegardens, where climatic and altitudinal factors are similar. In Chagga, Fernandes *et* al. (1984) have reported the presence of 58 herbaceous and 13 woody crop plants. In a study conducted in the homegardens of Welayita and Gurage zones of Southern Ethiopia, a total of 60 crop plants were recorded with an average of 14.4 crops per farm (Zemede Asfaw and Zerihun Woldu, 1997). The total number of species as well as the average number of crops per farm is higher than what was reported for Welayita and Gurage homegardens.

The abundance of crops in these gardens is generally uneven because some species, particularly enset and coffee are more dominant. The dominance of the two crops is due to their wide socioeconomic and ecological roles in the systems. Enset is the main staple food which is produced in large quantities, while coffee is the major cash crop. They can be grown in integration with each other and with under-storey as well as upper-storey crops. This intricate combination of plants plays an important ecological role by reduction of erosion, provision of organic matter, and regulation of water and temperature. On the average, the two crops accounted for 63% of the crop area, but variations occur in the area share of crops across the sites. Increasing market opportunity that opened up due to road access is leading to expansion of new cash and subsistence crops affecting the area share of these major crops. The heterogeneity of crops in the farms is highly correlated with distance to a highway. Both Evenness (E) and Shannon (H') indices increased significantly ($P<0.01$) with increasing proximity to a highway. In homegardens located near roads the share of coffee and enset is reduced by chat, pineapple, maize and sweet potato, and this contributes to a better evenness.

Is crop diversity distributed evenly within the homegardens?

As it is indicated earlier, distinct farm units can be observed in these gardens because of the dominant crops in them. The presence of such distinct zones in homegardens was also reported by Mendez *et* al. (2001) for the homegardens of Nicaragua, where they used the term "management zones" or "micro zones" to describe these units. In the homegardens of Sidama, enset and coffee are often grown together, and in integration with different crops. Yet, a distinction can be made between enset units or coffee units depending on which one of the two crops is dominant on a particular unit. Enset and coffee and the other crops intercropped with them constitute an average of 80% of the crop areas. The high proportion of the two perennial crops and their intimate association with different crops and trees leads to identification of the farms as Agroforestry homegardens. However, it should be noted that there are some patches in these systems that are less complex in structure and less rich in species. These units belong to the crops such as maize, chat, pineapple, sweet potato and sugarcane. At present, maize, chat and pineapple are expanding at the more accessible sites, and this expansion takes place by reducing the proportion of the integrated enset-coffee units. In comparison to the enset-coffee multistorey units, the other units have less associated crops mainly due to ease of management and light demanding nature of the species.

A farm landscape with a mosaic of patches (units) can be considered more diverse than one with large monoculture fields. However, the conversion of integrated multistorey systems to create new patches of somewhat monoculture plots, is a rather negative development of diversity. The dynamics in the development of patches in these systems is discussed in the following by considering examples of the three expanding crops, maize, chat and pineapple.

***Maize**:* Maize is the second important food crop in the research areas following enset. It has been cultivated at small scales within the enset-coffee multistorey agroforestry units. Farmers grew it wherever open space is available within the integrated system so that it shares the available resources. In these land use systems, the cultivation of maize in separate and large plots is a new development largely influenced by two main factors: 1) increasingly smaller land holdings that force small holders to produce annuals crops for immediate cunsumption. 2) agricultural extension practices, in which maize is promoted as one of the priority crops to improve food self-sufficiency in the country. Farmers obtain loans to buy improved seed and fertilizer, and they are advised to grow the crop in a continuous area to facilitate cultivation and improve efficiency of fertilizer use. This necessitates removal of other crops, leading to the development of monoculture maize plots within these agroforestry systems. Farmers report that yield of maize has increased but there was a decline in price of maize that made it difficult to pay the debt for the inputs. Furthermore, the system has introduced elements of dependency on external inputs and the overall diversity and complexity of the farms is decreasing. This extension system could be more applicable to cereal based farming systems elsewhere in the country. However, its large-scale implementation in these perennial crop based land use systems could jeopardize not only cropping diversity but also the overall integrity and stability of the systems. At present, average area share of maize is about 16.4%, and it has reached as high as 40% in some sites, particularly those located alongside roads.

Chat: Chat is the second important cash crop in the area next to coffee. Its succulent, young and fresh leaves are chewed as stimulants. Over the last two decades, demand for chat has increased, and thus its production, at some sites. An advantage of chat over coffee as a cash crop is that it can be harvested 2-3 times a year, and this results in a fair distribution of annual farm income. Many farmers also believe that it has a higher rate of return when compared to coffee. Over the last few years the coffee price has gone down and chat was more profitable. However, proximity or easy access to market is very important to chat production because the produce should be delivered to consumers while fresh. Farmers who have easy access to markets or roads have therefore increased the production of chat, largely at the expense of coffee. Such a rivalry in land use between coffee and chat has been reported earlier for the eastern parts of the country (Amare Getahun and Krikorian, 1973) where chat is widely grown for huge local consumption and for export to neighboring countries. Chat can grow to a tree, but it is kept low and bushy through continuous pruning. The bushy nature could hinder incorporation of other crops. On the other hand, chat unlike maize, has a continuous ground cover throughout the year and it is not dependent on external inputs. Hence, from economical and ecological point of view, there are relatively few direct reasons to advise against this crop.

Pineapple: Pineapple is the latest entry into these farming systems. It is expanding in PAs such as Tesso and Qomato that have lower altitude, warmer temperature and access to a major road. The combination of climatic suitability and access to roads has motivated the farmers to grow more pineapple as a cash crop. Traders from cities as far as Addis Ababa (350 kms away) come with trucks to buy these fruits and retail them to cafés and restaurants for juice making. Some young farmers and farmers' sons also sell pineapple fruits alongside the roads to travelers. At Tesso PA an average of 11.4% of the crop areas is covered with pineapple, with values that reach as high as 32%. In most cases, pineapple is grown in separate units except when the stands are few in which case they are integrated into the enset and coffee units. During the farm visit, it was observed that one farmer was growing pineapple in a systematic intercropping scheme with enset and coffee where every third row was planted with pineapple. Moreover, other vegetables were also grown in the open spaces. The farmer claims that the yield is high and he did not have any problem in the management. Obviously, such a growing pattern would be more beneficial in terms of long-term sustenance of the resources.

The above examples clearly demonstrate that farmers respond towards external socioeconomic factors such as improved marketing opportunities by changing the composition of crops in their homegardens. Such responses of farmers leading to change in the composition of crops in homegardens were also reported elsewhere (Wiersum, 1982; Soemarwoto and Conway, 1991; Kaya *et* al., 2002). Nevertheless, such a change in the multistorey nature of the homegardens could affect the positive attributes associated with their structural complexity and composition. The multistorey configuration and high species diversity of homegardens is believed to avoid the environmental deterioration commonly associated with monocultural production systems (Fernandes and Nair, 1992). It is also argued that such a diversity fosters recycling of nutrients, increase efficiency in the use of moisture, nutrients and light, and reduce the incidence of weeds, pests and disease (Altieri, 1995). The expansion of monoculture plots in these homegardens could therefore affect all these beneficial attributes, and thereby the long-term sustainability of the systems. Research and extension endeavors should therefore focus on looking for means of integrating these crops into the existing multispecies systems, and on improving productivity of the systems as a whole.

Richness and Evenness in functional groups of crops

The number of crop species grown in a farm is an important indicator of diversity. However, from the utility point of view, it is not only the number that matters, but also the diversity in functions of the crops. In order to fulfil the dietary and cash requirements of the households, food crops composed of carbohydrates, proteins, fat, vitamins, as well as cash crops should be fairly represented in the systems. The average number of commodity groups per farm was 8.1 and the variability among the households is not large. The main staple food enset is primarily an energy producing food. Nutritionally, the composition of crops widely produced and consumed in these farming systems is largely dominated by energy producing food crops (Table 3.7). Root and tuber crops and cereals that cover nearly half of the crop fields are predominantly energy producing crops.

Table 3.7 Common food crops, area of production and nutrient value

Commodity group of crops	Main food crops	Mean farm area coverage (%)	Nutrient value per 100 gram of edible portions	
			Calorie	**% protein**
Root and tuber crops	Enset	26.4	190	1.5
	Sweet potato	2.4	114	1.5
	Yam	0.8	41	1.0
Cereals	Maize	17.0	363	10.0
Vegetables	Cabbage	1.6	28	2.0
Fruits	Avocado	0.8	165	1.5
	Banana	0.6	116	1.0
Pulses	Haricot bean	1.1	339	24.0

Note: The source for the nutrient value is World Food Program (1991).

The average area of cabbage production is only 1.6% of the total crop area, but according to farmers, yield per unit area is sufficiently high to cover household consumption. Since leafy vegetables such as cabbage are very rich in vitamins (Marten and Abdoellah, 1988), the vitamin supply in the nutrition of the households is expected to be sufficient. A deficiency in the diet of households, mainly poor ones, is expected in the supply of protein. This is because the area allotted to bean production is generally small and the yield is low. Farmers estimate the yield to be about 1000kg per hectare. This means that a poor household with a land holding of 0.5 hectare allocates an average area of 50 m^2 of land to beans and harvests about 5 kgs of produce per year. Although it is necessary to make nutrition analyses to determine consumption requirements, it is clear that the above amount can not satisfy protein needs of an average small family of 5 persons for the whole year. When it comes to rich and medium farmers, the production is relatively high and they also obtain protein from animal products such as meat and eggs. For some of the poor farmers, such animal products are unaffordable. In general, pulses and oil crops represent 1.1% of the total food crop area but the production is not sufficient to fulfil nutritional requirements of many households.

Composition of crops across the sites

The enset-coffee agroforestry homegardens of Sidama have basic crop species assemblages composed of crops such as enset, coffee, maize, cabbage, beans, avocado and banana, which are common among all farms but differences exist in the distribution of less common species. The major difference in species composition was observed on two sites, Chefasine and Abela Tula, where the composition of crops grown differed from the rest by an average of more than 50%. Here, a suitable marketing and road infrastructure and proximity to a big town (Awassa) has encouraged the farmers to grow more chat for marketing. They also grow a larger proportion of maize for consumption, and the number of crop species in the farms is generally low. It appears that these farmers have focussed on the production of few cash and food crops as they could purchase the others from the market. Such reactions of farmers towards favorable marketing conditions have also been reported elsewhere (Wiersum, 1982; Marten and Abdoellah, 1988; Kaya *et* al, 2002). The composition of crops in the low altitude sites of Tesso, Qomato and Tula Aposto is also different. In the first two cases, market access by a highway link has increased the share of cash crops, chat and pineapple while maize and sweet potato are also widely grown for consumption. In Tula Aposto, the share of enset is the lowest and thus additional food crops maize and sweet potato are grown at large.

On the other hand, in sites far from the major highways the composition of chat and pineapple is very low, and coffee and enset alone accounted for a minimum of 70% of the crop area. Therefore, the expansion of new cash and food crops in the more accessible sites has altered the composition of the major crops, and lead to identification of four different prototypes of the enset-coffee homegarden systems.

Variation in crop yield across the different prototypes of systems

The inclusion of high value crops such as chat and pineapple in these homegardens has resulted in higher monetary output in the new prototypes of the system. Chat and pineapple have high demand in towns and they are relatively easy to transport, and thus they have become popular cash crops among farmers located near major roads. Motivated by the high income, many farmers have allocated a significant portion of their farms to these crops. In some of these sites, larger proportion of land is brought under cultivation of maize for home consumption creating large patches of maize plots in these systems. Moreover, chat and pineapple are often grown as monocrops and without shade. The development of such cropping patterns is, therefore, gradually changing the structure of the systems form a complex, four storey vegetation into a simple, single or double storey vegetation. Along with this simplification, it is expected that the ecological benefits associated with the complexity and multistorey nature of the systems could decline. Thus, the development of such new prototypes with cash crop components could be economically attractive, but it might affect stability and long-term sustainability of the systems.

3.5 Conclusions and recommendations

The enset-coffee homegarden agroforestry systems of Sidama are generally diverse and complex agroecosystems where a total of 78 and an average of 16 crop species of different stature and life cycle are grown in an intimate association. The abundance of crops is not even because of the dominance of few species notably enset and coffee, which are the key species in these systems. Enset is the staple food and coffee is the major cash earner in the areas, and thus they are produced in large quantities. A total of 10 functional (commodity) groups of crops are present in these systems out of which an average of 8.1 groups exists in each farm. The presence of crops with different functions fulfils the nutritional and monetary needs of the households. The basic food crops, enset and maize, which are rich in carbohydrates are supplemented by pulses, vegetables, fruits and animal products that provide proteins, fats and vitamins. This contributes to a balanced dietary composition, which is necessary for healthy and productive farm families. The income from cash crops contributes to fulfilment of their material and other needs.

The diversity of crops varies among plots within a farm. The enset and coffee plots are associated with an average of 13 crop and many other tree species displaying 3 to 4 storeys. On the other hand, plots of maize, chat, pineapple and other crops have few associated species and show only one or two storeys. Variation occurs in the diversity and area share of major crops among the sites. In sites that are linked with external markets through better marketing and road infrastructure the number of species is generally low. This is because farmers focussed on production of major cash and food crops. In these sites the share of enset and coffee is declining and cash crops such as chat and pineapple are expanding. The reduction in areas of enset has called for an increase in area of annual food crops such as maize and sweet potato. The expansion of these crops on the accessible sites has therefore led to the development of distinct land use within the coffee-enset agroforestry systems where four different prototypes of the system could be recognised.

The combination the two native perennial crops, enset and coffee, and their integration with a multitude of other crops and trees is beneficial from an ecological as well as a socio-economic point of view. These systems contribute to control of pests and diseases, control of erosion, amelioration of the microclimate, and maintenance or enhancement of soil nutrient levels. As a result, they are less dependent on external inputs. This explains why the homegardens of Sidama have been supporting a very dense population of 367 to 562 persons per square kilometre. The management of multispecies agroecosystems, based on perennial crops fulfilling the subsistence and cash needs of households, enhances agricultural sustainability. On the other hand, the replacement of the multistorey enset-coffee plots with monoculture plots of new cash and food crops, particularly annual crops is likely to reduce the ecological benefits derived from the integrated and complex systems, and threaten their long-term sustainability.

Hence, attempts to improve these homegardens should not affect the integrated nature of the systems. To this effect, research and extension efforts should aim at developing techniques to integrate new crops into the systems without affecting their integrity. An example in this regard is the ongoing effort in the dissemination of coffee varieties that are resistant to Coffee Berry Disease (CBD). Different CBD resistant coffee varieties that are developed by the national coffee research institution are being widely planted by farmers replacing the susceptible ones. Most of the new varieties give higher yield and they have a manageable size, adding to their acceptability by farmers. Obviously such changes contribute to improved performance of the systems.

Likewise, improvements can be made on other components while maintaining the diversity and complexity. For instance, most of the fruit trees such as avocado, guava, papaya, white sapote and mango are giant trees bearing fewer fruits, and thus with low production efficiency. Research and extension efforts should aim at introducing high yielding varieties that could improve productivity of the systems. Since the enset diet is rich only in carbohydrates, attempt should also be made to introduce or expand high yielding pulses and vegetable crops. This would further enhance the nutritional well-being of the people while improving efficiency of the systems.

Appendix 3.1 List of crop species found in the agroforestry homegardens of Sidama and their frequency of occurrence.

Scientific name	Family	English name	Vernacular names		Frequency
			Sidama	Amharic	(n=144)
Root and tuber crops					
*Enset ventricosum (*Welw.*) Cheesman*	Musaceae	Enset, false banana	Wesse	Enset	144
Dioscorea alata L.	Dioscoriaceae	Yam	Bohe	Boyna	85
Colocasia esculenta (L.) Schoot.	Araceae	Taro	Qolchoma	Godere	73
Ipomoea batatas (L.) Lam.	Convolvulaceae	Sweet potato	Metatesa	Sikuar dinich	60
Manihot esculenta Cranz.	Euphorbiaceae	Cassava	Kassava	Kassava	12
Solanum tuberosum L.	Solanaceae	Potato	Dinich	Dinich	9
Beta vulgaris L.	Chenopodiaceae	Beet root	Qey sir	Qey sir	7
Daucus carota L.	Apiaceae	Carrot	Carota	Carot	3
Dioscoria bulbifera L.	Dioscoriaceae	Aerial yam	Kotehare		1
Vegetables					
Brassica integrifolia (West) O.E. schulz	Brassicaceae	Kale	Shana	Gomen	143
Cucurbita pepo L.	Cucurbitaceae	Pumpkin	Baqula	Duba	119
Capsicum frutescens L.	Solanaceae	Hot pepper	Qarya	Qarya/Berbere	62
Brassica oleracea L.	Brassicaceae	Ethiopian kale	Bulo	Yegurage gomen	48
Lycopersicon esculanta L.	Solanaceae	Tomato	Timatim	Timatim	23
Capsicum annuum L.	Solanaceae	Chilly	Mitmitta	Mitmitta	17
Solanum villosum L.	Solanaceae		Tunaye		13
Allium cepa L.	Alliaceae	Shallot	Duma sunkurta	Qey shinkurt	5
Brassica oleracea var. capitata	Brassicaceae	Cabbage	Tiqel Gomen	Tiqel gomen	5
Latuca saliva L.	Asteraceae	Head lettuce	Selata	Selata	3
Allium porrum L.	Alliaceae	Leek	Baro	Baro	3
Allium sativum L.	Alliaceae	Garlic	Tuma	Nech shinkurt	2

Scientific name	Family	English name	Vernacular names		Frequency
			Sidama	Amharic	(n=144)
Pulses					
Phaseolus vulgaris L.	Fabaceae	Common bean	Wahe	Adenguare	143
Phaseolus lunatus L.	Fabaceae	Lima bean	Koyra	Adenguare	43
Vicia faba L.	Fabaceae	Faba bean		Baqela	4
Pisum sativum L.	Fabaceae	Pea		Ater	3
*Cajanus cajan (*L). Mill.	Fabaceae	Pigeon pea		Yewof ater	3
Cereals					
Zea mays L.	Poaceae	Maize	Bedela	Beqollo	144
Sorghum bicolor (L.) Moench	Poaceae	Sorghum	Beshenqa	Mashilla	44
Eragrostis tef (Zucc.) Trotter	Poaceae	Tef	Gashe	Tef	9
Hoedeum vulgare L.	Poaceae	Barely	Hayte	Gebs	3
Triticum sativum L.	Poaceae	Wheat	Qemede	Sinde	3
Fruits					
Persea americana Mill.	Lauraceae	Avocado	Abukato	Abukato	124
Musa paradisiaca L.	Musaceae	Banana	Muze	Muz	120
Psidium guajava L.	Myrtaceae	Guava	Saitonne	Zeitun	62
Citrus sinensis (L.) Osbeck	Rutaceae	Sweet orange	Burtukanne	Bertukan	54
Casimora edulis La Llave & Lex.	Rutaceae	White sapota	Kasmire	Kazmir	42
Ananas comosus (L.) Merr	Bromeliaceae	Pine apple	Ananas	Ananas	34
Prunus persica (L.) Batsch	Rosaceae	Peach	Koke	Kok	22
Carica papaya L.	Caricaceae	Papaya	Papaye	Papaye	22
Passiflora edulis Sims	Passifloraceae	Passion fruit	Hopi	Hopi	19
Annona reticulata L.	Annonaceae	Bullok's heart	Gishta	Gishta	16
Mangifera indica L.	Anacardiaceae	Mango	Mango	Mango	12

Scientific name	Family	English name	Vernacular names		Frequency
			Sidama	Amharic	(n=144)
Cyphomandra betacea (Cav.) Sendt.	Solanaceae	Tree tomato	Timatim Zaf	Timatim zaf	11
Fragaria vesca L.	Rosaceae	Strawberry	Enjori	Enjori	7
Citrus aurantifolia (Christm) Swingle	Rutaceae	Lime	Lomi	Lomi	6
Punica granatum L.	Puniaceae	Pomgrante	Roman	Roman	2
Stimulants					
Coffea arabica L.	Rubiaceae	Coffee	Buna	Buna	144
Chata edulis (Vahl.) Forssk.ex Endl.	Celastraceae	Khat	Chat	Chat	82
Nicotiana tobacum L.	Solanaceae	Tobacco	Tembo	Tembaho	12
Spices and condiments					
Capsicum frutescens L.	Solanaceae	Hot pepper	Qarya	Qarya/Berbere	62
Ruta chalepensis L.	Rutaceae	Rue	Senkurta	Tenadam	24
Capsicum annuum L.	Solanaceae	Chilly	Mitmitta	Mitmitta	17
Afromomum korarima (Braun) Jansen	Zingiberaceae	Falso cardamon	Korerima	Korerima	9
Zingiber officinale L.	Zingiberaceae	Ginger	Janjibello	Zingibel	5
Rosmarinus officinalis L.	Lamiaceae	Rose mary	Sega metbesha	Sega metbesha	5
Ocimum basilicum L.	Lamiaceae	Sweet basil		Besobela	4
Lippia adonensis Hochst. Ex Walp.	Verbenaceae			Koseret	4
Piper nigrum L.	Piperaceae	Black pepper		Qundo berbere	1
Nigella sativa L.	Ranunculaceae	Black pepper		Tiqur azmud	1
Oil crops					
Ricinus communis L.	Euphorbiaceae	Castor	Qenboo	Gullo	62
Arachis hypogea L.	Fabaceae	Ground nut	Ocholoni	Lewz/ocholoni	13
Carthamus tinctorius L.	Asteraceae	Safflower	Suf	Suf	4

Scientific name	Family	English name	Vernacular names		Frequency
			Sidama	Amharic	(n=144)
Brassica carinata A. Br.	Brassicaceae	Ethiopian mustard		Gomen zer	27
Linum unisatissimum	Asteraceae		Shalela	Telba	1
Medicinal plants					
Ocimum gratissimum L.	Lamiaceae			Damakesse	19
Foeniculum vulgare Mill.	Apiaceae	Fennel		Inslal	3
Otostegia integrrifolia Benth.	Lamiaceae			Tenjut	2
Artemisia absinthium L.	Asteraceae			Ariti	1
Fragnance plants					
Ocimum gratissimum L.	Lamiaceae			Damakesse	19
Lippia adoensis Hochst. Ex Walp	Verbenaceae			Kesse	17
Cymbopogon citratus (DC.) Stapf.	Poaceae	Lemon grass		Tej-sar	2
Other crops					
Rhamnus prinoides L' herit	Rhamnaceae	Rhamnus	Taddo	Gesho	101
Saccharum officinarum L.	Poaceae	Sugarcane	Shenkora	Shenkorageda	78
Lagenaria siceraria (Mol.) Stardl.	Cucurbitaceae	Bottle gourd		Qil	7
Agava sisalana Perr.	Agavaceae	Sisal	Qacha	Qacha	6
Gossypium herbaceum L.	Malvaceae	Cotton		Tit	3
Sorghum dochna (Forsk.) Snowden	Poaceae	Sweet stalk sorghum		Tinqish	1
Pennisetum purpureum Schumach *)	Poaceae	Elephant grass		Zihone sar	17
Chloris gayana Kunth *)	Poaceae	Rhodes grass	Rodes	Rodes	3
Desmodium unicinatum (Jacq.) DC *)	Leguminoseae	desmodium			1

* introduced forage crop

CHAPTER 4

4. Factors influencing the diversity and composition of crops in homegardens

4.1 Introduction

Agriculture in much of the tropics is characterized by small-holder farmers who grow and maintain large number of crop species and varieties. Crop diversification is a deliberate strategy of farmers to ensure subsistence and it has several advantages. These include, yield stabilization, risk reduction, staggered use of family labor, multiple production, making use of a variety of soils and agro-climatic conditions, and increased resource productivity over time (Soemarwoto and Conway, 1991; Almekinders *et* al, 1995; Netting and Stone, 1996; Bayush Tsegaye, 1997).

The homegarden agroforestry systems of Southern Ethiopia are one of such diverse multi-species agroecosystems that could sustain a very dense population for centuries. These homegardens are characterized by two dominant native perennial crops, enset and coffee. Enset (*Enset ventricosum* (Welw.) Cheesman) is a multipurpose crop and a staple food for about 10 million people in the region. Coffee (*Coffea arabica* L.) is the major cash crop that plays significant role in the household as well as regional and national economies. The two crops are grown in an intimate association with several herbaceous and woody crops as well as trees in multistorey configurations. Livestock are also important components of the systems. Unlike most homegardens elsewhere that are defined as supplementary food production units (Ninez, 1987; Hoogerbrugge and Fresco, 1993), the homegardens in many parts of Southern Ethiopia are extended farm systems from where households derive all their subsistence and cash needs.

A study conducted to determine the diversity and composition of crop species in these homegardens (Chapter 3) indicated that diversity is generally high but that there exists a large difference among sites and between farms within a site. Crop species richness and diversity as well as richness in functional groups of crops varied considerably. The study also showed that although the enset-coffee agroforestry homegardens have everywhere a common basic crop species assemblage, the composition and area share of the major crops varied across the sites. In some areas, the share of the basic crops, enset and coffee is significantly reduced and crops such as maize, chat (*Chata edulis*) and pineapple are expanding, leading to identification of different prototypes of these systems. In the areas where such land use changes are taking place, the integrated multi-storey gardens are getting smaller and patches of less complex and sometimes monoculture plots are evolving. This development is likely to affect the long-term sustainability of the systems because studies indicate that the diversity and complex structure of homegardens is responsible for positive agroecosystem functions (Jensen, 1993; Wojtkowski, 1993). Okafor and Fernandes (1987) have also reported that replacement of compound farms (homegardens) with monocropping in Nigeria has resulted in severe soil degradation and poor yields. It is also argued that intensification could increase production but in many cases it reduces output stability and resource use efficiency and enhances over-exploitation of the resource base (Almekinders *et* al., 1995). The expansion of such land use in these complex multistorey systems should therefore be observed with caution. But, why is the diversity and composition of crops different in these agroecologically similar areas, or why do farmers alter the diversity and composition of crops in their farms? Some earlier reports have indicated that access to markets (Wiersum, 1982; Marten and Abdoellah, 1988: Soemarwoto and Conway, 1991), access to road (Kaya *et* al., 2002), altitude (Soemarwoto and Conway, 1991), and farm size (Wiersum, 1982; Jacob and Alles, 1987; Rico Gray, *et* al, 1991) affect the diversity and composition of crops in homegardens. Identifying which factors are responsible for the variation in the present study areas is important to understand how farmers manage diversity under different circumstances, and this might contribute towards the design of strategies where diversity is better managed to enhance agricultural sustainability.

The present study aims at identifying the factors that affect crop diversity and area share of crops in the enset-coffee homegarden agroforestry systems of Southern Ethiopia. Specific objectives are, to identify the socio-economic and biophysical factors that affect the farms' a) crop species richness and heterogeneity b) richness and heterogeneity of functional groups of crops, and c) area share of the major crops.

In the present study only cultivated herbaceous and perennial crops such as fruit trees are considered. Trees grown for their wood products and ornamental plants are not included.

4.2 Materials and methods

The study was undertaken in 12 sites (Peasant Associations) selected from four woredas (districts) in Sidama, Southern Ethiopia where these agroforestry systems are practiced. The Peasant Associations (PAs) and households were selected on the basis of the major variables that were expected to affect crop diversity. The PAs were selected on the basis of their access to highways, access to markets and altitude. At household level farm size and family labor, which are highly correlated with economic well being of the household, were expected to influence crop diversity. Thus, within a site, households were selected on the basis of their economic status. From each category of economic group, four households were selected at random, making a total of 12 households per PA and 144 households for the whole study. In addition to these, other variabilities such as involvement in off-farm activities, family size, age of household heads were recorded in the surveys. These variables and their characteristics are shown in Table 4.1.

Methods of data collection

Data were collected from 144 sample farm households. Often, each household has one piece of land with a house (houses), and the gardens surrounding it. Some farmers have an additional piece of land within a short distance in the same PA, but the pattern of cropping is often similar and there is often a house in it. Thus, it is still another set of homegarden. Data were collected from all homegardens (farms) that are under the disposal of a household. The homegardens presented here should therefore be understood as equivalent to a 'farm' system.

Table 4.1 The variables used in the analysis and their characteristics

Factors	Range of values	Overall mean	Remarks
Physical environment			
- Altitude of the farm	1520-2040 (meters a.s.l.)	1828 m	
- Slope of the farm	0 –45%	10%	
Socio-economic environment			
- Distance of farms to market	0.04 – 6.0 kms	2.1 kms	
- Distance to major roads (highways)	0.02 – 26 kms	9.0 kms	
- Farm size	0.18 – 7.46 ha	0.75 ha	
- Number of livestock	0 - 21 TLU*	3.1 TLU	
- Involvement in off-farm activities	Yes/no		30% of the farmers involve in wage labour, carpentry, trading or other income generating activities
- Family size	3-22 persons	8.3 persons	
- Farm labour force	2-11 persons	4.9 person	
- Age of the household head	25-92 years	48 years	
- Educational status of the household head	Illiterate to secondary school complete		23% illiterate, 22% reading and writing 32% elementary school, 20% secondary school, 3% completed secondary education
- Ethnic background			93% Sidama, and 7% others
- Gender of the household head			95% male headed, 5% female headed

* TLU: A Tropical Livestock Unit –TLU (Heady, 1975), is a standard used to quantify different livestock types and sizes using a cattle with a body weight of 250 kilograms.

In order to analyze the factors that affect diversity and composition of crops, species richness and heterogeneity of crops as well as the area share of major crops of each farm had to be characterized. To achieve this, farm level data were collected on the number of crop species, number of individuals of each species and area share of the crops. In addition to these, data were collected on other relevant environmental factors.

Data Analysis

The diversity of crops was characterized by calculating species richness and species evenness for each farm. An additional measure of evenness, which compares observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated (see chapter 3.2). The area share of the major crops was also calculated for each farm.

The dependency of diversity indices on physical and socioeconomic environments was determined using a separate multiple regression model for each index. Thus each model included a number of independent variables and one of the dependent variables. The dependent variables included species richness, Shannon index, measure of Evenness, Number of functional groups, Shannon index of functional groups, measure of Evenness of functional groups and area share of the major crops.

4.3 Results

The results of the characterization of crop diversity have shown wide variations in crop species richness and evenness across the different sites of the enset-coffee homegardens of Sidama (see chapter 3). Stepwise linear regression analysis of the indices of diversity and area share of major crops on physical and socioeconomic environments of farmers showed that the performance of the models on the indices was different (Tables 4.2 and 4.3). Values of adjusted R^2 ranged from 0.05 to 0.40. Among the indices, the model largely explained the variation in area share of the major crops. The analysis also revealed that not all factors are important in influencing crop species richness and diversity of farms. Access to markets, access to major roads, altitude, slope of the farm and livestock holding were among the most important factors that influenced species richness and evenness of crops. In the following, each factor and its effects on crop diversity and composition are presented.

Physical environment

Altitude: Altitude had an effect on evenness of crops. Evenness decreased with increasing altitude. Altitude had also affected the area share of major crops. At the lower altitudinal zones, the share of crops such as sweet potato and pineapple is high while that of the staple crop enset increased with altitude. The decrease in the area share of the dominant crop enset and its replacement with the new crops sweet potato and pineapple has therefore contributed to a better evenness of abundance at the lower altitudes.

Slope of the farm: The variation in slope of farms had affected heterogeneity of crop species. Evenness increased with increasing slope. Slope of the farm also had a positive effect on the share of coffee; its area share increased with increasing slope.

Socioeconomic environments

Access to market: Access to markets had effects on species richness and heterogeneity of crops. Species richness increased with distance of farms to markets but evenness of their abundance decreased. Evenness in the number of functional groups of crops also decreased with distance to markets. Access to market affected also the area share of major crops: With increasing distance to markets, the share of coffee increased but that of chat and maize decreased. In other words, chat and maize have significantly reduced the share of coffee in farms that are close to markets.

Table 4.2. Results of multiple linear regression of diversity indices on farmers local and household environments

Factors	**Crop species**			**Functional groups of crops**		
	Richness (S)	*Shannon's index (H')*	*Evenness (E)*	*Richness (S)*	Shannon's Index (H')	*Evenness (E)*
Adjusted R^2	**0.10*****	**0.20*****	**0.23*****	**0.05*****	**0.06*****	**0.12*****
Physical environment						
- Altitude of the farm	ns	-0.35**	-0.24*	ns	ns	ns
- Slope of the farm	ns	0.25**	0.16*	ns	ns	ns
Socio-economic environment						
- Distance to markets	0.20*	ns	-0.19*	ns	-0.18*	-0.29***
- Distance to major roads	ns	ns	-0.20*	0.16*	0.17*	ns
- Farm size	ns	ns	ns	ns	ns	ns
- Number of livestock	ns	ns	0.17*	ns	ns	ns
- Involvement in off-farm activities	ns	ns	ns	ns	ns	ns
- Family size	ns	ns	ns	ns	ns	-0.25**
- Number of farm labour force	0.18*	ns	-0.21*	ns	ns	ns

Note: ns = not significant; *, **, *** = F-test significant at P <0.05, 0.01, 0.001, respectively.

Table 4.3 Result of multiple linear regression of socio-economic and physical factors on area share of major crops

Factors	Proportional area share (%)					
	Enset	*Coffee*	*Maize*	*Chat*	*Sweet potato*	*Pineapple*
Adjusted R^2	**0.14*** **	**0.40*** **	**0.29*** **	**0.23*** **	**0.37*** **	**0.32*** **
Physical environment						
- Altitude of the farm	0.24*	ns	ns	ns	-0.50***	-0.55***
- Slope of the farm	ns	0.17*	ns	ns	ns	ns
Socioeconomic environment						
- Distance to markets	ns	0.17*	-0.18*	-0.19*	ns	ns
- Distance to major roads	0.25**	0.48***	-0.63***	-0.27***	ns	-0.19*
- Farm size	-0.28**	0.30***	ns	ns	ns	0.18*
- Number of livestock	0.21*	-0.16*	ns	ns	ns	ns
- Involvement in off-farm activities	ns	ns	ns	-0.23**	ns	ns
- Family size	ns	ns	ns	ns	ns	ns
- Number of farm labour force	ns	ns	ns	ns	ns	ns

Note: ns = not significant; *, **, *** = F-test significant at P <0.05, 0.01, 0.001, respectively.

Access to road: Here, only major roads that provide full access to all sorts of vehicles are considered. There are gravel and dirt roads in the research areas but they do not provide full access to transportation of goods since they are less frequented by public transport vehicles. Distance of farms to highways did not affect the richness in crop species, but it affected negatively the evenness. The effect of road access on area share of the major crops was particularly very significant. The share of the basic crops enset and coffee increased with the distance of farms to highways, but crops such as chat, pineapple and maize had larger share in farms that are close to highways. In general, access to markets and major roads has reduced the share of enset and coffee and resulted in increased share of other crops, mainly maize and chat.

Economic status of farmers: The households are grouped as poor, medium and rich on the basis of the resources they own. Basic indicators are used to distinguish between the three economic groups of farmers in the research sites (Table 4.4). Economic status is largely correlated with farm size (r=0.72), livestock holding (r=0.47) and farm labor force (r=0.47). Thus, most of the variations related to economic status are explained by these factors.

Table 4.4 Major socio-economic characteristics of the different groups of farmers

Indicators	**Economic groups**		
	Poor (n=48)	Medium (n=48)	Rich (n=48)
Farm size (hectare)	0.55	1.46	2.75
Number of livestock (TLU)	1.1	2.5	5.2
Labour force: - Adult labour	2.3	2.6	3.0
- Children aged 10-18	1.4	2.4	3.4
Area of land under cash crops (%)	38.3	45.5	52.1
Family size	6.4	8.5	10.2

Farm size: Farm size did not have any effect on crop species richness and evenness of farms, but it had a significant effect on the area share of major crops. The share of enset declined with increasing farm size, but cash crops such as coffee and pineapple increased. A closer look at the area share of the four widely grown crops (enset, maize, coffee and chat) across the different economic groups of farmers indicated that the share of food crops declined with increasing wealth, while that of cash crops, particularly coffee, increased (Figure 4.1). The proportion of maize in poor farmers' fields is high due to insufficient stands of mature enset, which is in turn associated with scarcity of land. When the two cash crops coffee and chat are compared, chat did not continue to grow with economic status like coffee. It was rather the medium farmers who had a higher proportion of chat.

Number of livestock: The number of livestock (TLU) has affected the area share of enset and coffee, but the effects were different. The share of enset increased with livestock holding but the area of coffee decreased.

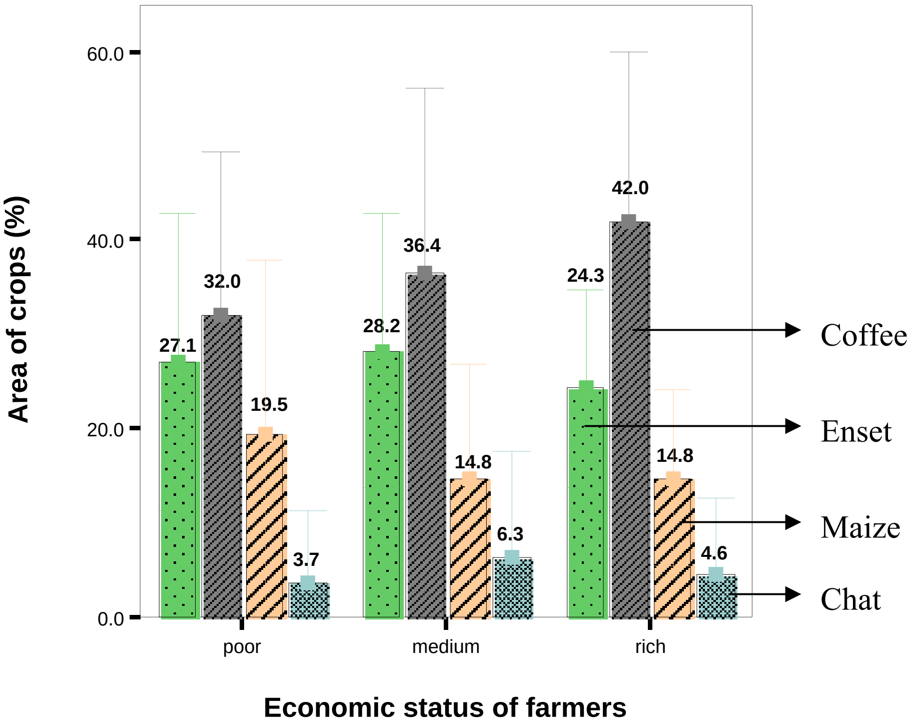

Figure 4.1 Area share of major crops in the different economic categories of farmers

Farm labor force: Crop species richness of farms increased with increasing farm labor force, but evenness decreased.

Involvement in off-farm activities: Farmers involved in off-farm activities are expected to have less time for the management of their farm, and this could affect crop diversity and composition. However, involvement in such activities of farmers has affected only the area share of chat. This is understandable because chat needs intensive management and farmers engaged in such activities may not have enough time to manage chat for income generation.

Family size: A farm family refers to all members of the household who live in the same house(s) permanently. Increase in family size is associated with high consumption of food. Thus, it is expected that the share of basic food crops (enset and maize) would be very high and affect negatively the evenness of species. However, family size affected only the relative evenness in the number of functional groups of crops.

Other socio-economic factors such as, age, educational status and gender of the household head, as well as ethnic background did not have any effect on crop diversity and area share of major crops.

4.4 Discussion

Several socio-economic and physical factors related to household and external environments of farmers were hypothesized to affect the diversity and area share of crops in farms, but only some of them were found important. Moreover, the effects of each factor on the indices varied considerably.

Biophysical factors, altitude and slope of the farms, have affected diversity of crop species. In the lower altitude sites where the temperature is higher, the share of crops as sweet potato and pineapple is high because of their adaptability. However, this is also associated with road access, because most of the low altitude sites also have better access to the road that facilitates marketing. Soemarwoto and Conway (1991) have reported a decrease in plant species diversity of homegardens with increasing altitude. In the present study, altitude did not have any effect on species richness. It should, however, be noted that this comparison is made between sites which belong to the same agro ecological zone. If we go up to another agroeoclogical zone, locally called *Dega* where the altitude is above 2300 m.a.s.l., the temperature is low and plant diversity is generally low (personal observation).

Slope of the farm has affected positively the evenness of crops. This could be attributed to the presence of different micro-environments that are suitable to different types of crops. In hilly farms, the house is often located on the top and the crop fields stretch down the slope up to a creek or a swampy field at the bottom of the slope. Steep slopes are often covered with perennial crops. The bottom of the slope where water stagnates sometimes, is often used to grow plants such as sugarcane, eucalypts and bamboo or it is set-aside for grazing. Such micro-site differences are so important that when members of a family share inherited land, they divide it along the slope so that the different site conditions are fairly well represented in each member's share. The presence of such different soil and microclimatic conditions suitable only for specific types of crops could have therefore contributed to a better evenness in the share of crops.

Access to market, either through the physical proximity of the market itself or through a link created by road infrastructure, has affected significantly most of the diversity indices but the effects were not always similar. Farmers close to markets grow relatively fewer crop species, because the market access encourages them to focus on the production of marketable products and to purchase other necessary products for consumption. These findings confirm earlier reports which indicated that species diversity of homegardens located close to market areas is low because farmers prioritize few commercial crops (Wiersum, 1982; Marten and Abdoellah, 1988; Jensen, 1993). Improved market access due to road construction is also reported to have similar effects (Kaya *et* al., 2002).

On the other hand, access to major roads did not affect crop species richness of farms. In road-access sites, farmers produced most of the crops necessary for their subsistence, but they reduced significantly the share of enset and coffee in favor of other cash crops whose marketing was realized due to road access. In order to compensate for the low share of the staple food, enset, the farmers increased the share of annual food crops mainly maize and sweet potato. A situation, where such a replacement of traditional staple crops took place, has also been reported for the Chagga homegardens in Tanzania (Fernandes *et* al., 1984), where maize was gradually replacing the staple food, banana.

Access both to market and major roads have resulted in a better evenness (uniformity in abundance) of crops. This is due to the decrease in the share of the basic crops (enset and coffee), and expansion of other cash and food crops. Among these factors, the effect of road access was more prominent in influencing the area share of major crops. As compared to the local markets, road access has effectively linked the farms with the external markets. Accordingly, many farmers are gradually shifting from the traditional cash crop (coffee) to crops such as chat and pineapple to exploit marketing opportunities. Chat is a mild stimulant and its succulent and fresh leaves are consumed. An advantage of chat over coffee as a cash crop is that it can be harvested 2 to 3 times a year, and this results in a fair distribution of annual farm income. Some farmers also believe that it has a higher rate of return when compared to coffee. Both chat and pineapple have high demands but they are perishable and they need to be delivered to consumers immediately. The road access has provided the farmers with such means.

The change in land use is sometimes associated with introduction of external inputs. This is particularly true for maize. In these systems, maize was normally grown in any available open space within the integrated agroforestry systems. In such conditions it shared an average of 10-15% of the cropland. Over the recent years, its cultivation is expanding in most farms. Agricultural extension endeavors are also promoting its intensification through the use of improved seeds and fertilizers. The share of maize has therefore increased, largely on small farms and on farms that have access to roads and reached as high as 40% at some sites. The increasing share of maize, which is associated with increased use of external inputs, has therefore introduced elements of dependency on the hitherto self-sustaining systems. On the other hand, high input technology in such subsistence systems has several shortcomings such as high cost of inputs, poor adaptation of seeds, soil mining, and other problems related to availability and timely distribution of inputs including new seeds (Bayush Tsegaye, 1997). Therefore, technological advancements in such subsistence systems can often not be realized with external inputs, but through a complete and more efficient utilization of available resources (Almekinders *et* al., 1995).

In general, the stability of the enset-coffee homegardens is largely dependent on the positive socioeconomic and ecological attributes of enset: a) It can feed more people per unit area of land than any other crops grown in Ethiopia (Admasu Tsegaye, 2002), b) It provides multiple outputs, and c) It maintains and improves the resource base through positive ecological effects such as shading, soil erosion control, and improvement of organic matter (Asnaketch Woldu, 1997). The reduction of the enset area and its gradual replacement particularly with high input annual crops, could therefore destabilize the systems in the long run. Hence, attempts to improve production efficiency of the systems should not aim at changing the perennial basis of the systems and the share of enset, which have been responsible for the system's self-sustenance.

Among the household characteristics, farm size, farm labor force and livestock holding (which are all highly correlated with economic well being of farmers) have influenced some of the indices. Farm size did not have any effect on species richness as well and evenness of crops. This confirms earlier reports (Wiersum, 1982; Jacob and Alles, 1987; Okafor and Fernandes, 1987) which indicated relationships between farm size and cropping intensity, but not diversity.

Farm size and livestock holding affected the area share of enset and coffee in an opposite manner. The share of enset declined with increasing farm size but it increased with livestock holding. On the other hand, coffee increased with increasing farm size and declined with livestock holding. With increasing farm size, farmers can satisfy their subsistence needs and allocate increasingly larger proportion of their farm to cash crops. This explains why the share of enset is declining and that of coffee is increasing with farm size. On the other hand, enset is dependent on livestock for soil fertility maintenance and hence its area increased with increasing livestock number. Absence of livestock leads to poor enset yield resulting in food insecurity of households. This situation could force farmers to shift from enset to annual crops such as maize and sweet potato

Farm size is a very important factor that could affect stability of these systems. Poor farmers who are constrained with shortage of land allocate an average of 27% of their crop land to enset (Figure 4.1), but the yield is often insufficient to cover consumption requirements. This is because, the proportion of mature enset plants is often low and this situation forces farmers to harvest immature enset plants whose *Qocho* yield is low. Livestock holding, which is critical for enset cultivation (because of the manure), is also low and this negatively affects the yield of enset. When the yield of enset is not sufficient to feed the family and when farmers do not expect enset yield in the immediate future, they bring more land into cultivation of annual food crops, especially maize and sweet potato. Shortage of land is, therefore, the main cause for the increasing share of annual crops, which in turn is expected to affect the stability and resilience of the systems.

This shift from enset to annual crops is more pronounced when poor farmers with acces to road turn to the production of cash crops. In the road access sites the average enset area of poor farmers is 18% while 40% is allotted to annual food crops. But, in the remote sites, enset accounted for 32%, while annuals shared only 16% of the cropland, meaning that poor farmers in the remote sites obtain more of their subsistence from enset. The expansion of annual crops can be reversed by well-planned staggered planting of enset in which the crop is grown to full maturity. The appropriate time of enset harvesting is when it reaches the flowering stage when the accumulated dry matter is at its highest (Admasu Tsegaye, 2002).

The benefits of the high yield potential of enset can be realized by allowing it to grow to its full maturity which takes 6 to 8 years in the study areas. This would contribute towards food security and improvement of the systems, particularly of the small farms. To achieve this, the enset field should be divided into equal proportions of at least 6 age classes to ensure regular supply of mature enset. When the annual yield is not sufficient, more maize can be replaced by enset because the productivity of mature enset is much higher than that of maize. In this manner, more food can be produced from the area allotted to subsistence crops, while sustaining the resource base. Only during the establishment phase of these rotations, poor farmers could face food shortage and they might need assistance. But this is a very small cost to pay to improve productivity and sustainability of the systems. The shortage of manure to maintain soil fertility can be backed by the use of compost. A recent extension effort in the utilization of coffee husk for composting is for instance an encouraging start to improve productivity of enset. Apparently, these systems cannot continue to absorb the ever-increasing population but improvements can be made which would increase productivity while reversing the expansion of annual crops.

4.5 Conclusion

The enset-coffee homegardens of Sidama are species-rich agroecosystems where an average of 16 cultivated crop species are grown in each farm. These systems have basic species components that are common across all sites, while the species richness and diversity of crops as well as the area share of major crops differ across the sites. These variations are caused by different socioeconomic and physical factors. Crop species richness increased with distance of farms to markets and with the amount of labor force. Evenness (uniformity in abundance) of crop species decreased with altitude and also with distance to markets and highways.

Access of farms to highways has affected negatively the area share of the basic crops, enset and coffee. In road-access sites, the share of other cash and food crops such as chat, pineapple, maize and sweet potato is higher because of the improved marketing opportunities created by the road. The area share of pineapple and sweet potato declined with increasing altitude, and this showed the adaptability of the two species to lower altitudes where temperature is higher.

These homegardens have been supporting a very dense population of 367 to 562 persons per square kilometers. This figure is 6 to 10 times higher than the Ethiopian average of 55 persons per square kilometers. The ability of the systems to support such a large population has been due to the integrated perennial crop base of the systems where crop diversity and high productivity of enset contributed to stability and food security. The share of enset in most of these gardens is still high but it is declining in some areas, particularly in those linked to external markets due to road access. Poor farmers with a small land holding also have a higher share of annual food crops because seasonal food shortage forces them to harvest immature, low-yielding enset. The decline in the share of enset and its substitution by annual crops do not only reduce productivity, but it can also affect the stability and resilience of the systems. However, there are possibilities (e.g. deliberate annual planting) through which improvements can be made in productivity of enset and the other components while maintaining the perennial basis of the systems. Research and extension efforts should aim at exploring possibilities to enhance the agricultural sustainability in the areas.

CHAPTER 5

5. Diversity and composition of trees and shrubs in agroforestry homegardens of Southern Ethiopia

5.1 Introduction

Homegardens are multispecies agroecosystems where different herbaceous and tree crops as well as trees are managed in integration. Two types of homegardens can be recognized in the tropics. The first and common one consists of small, supplementary food production units around houses, such as the homegardens of Java (Wiersum, 1982; Soemarwoto, 1987), where there are additional farm fields for food production. In the second type extended farm systems are located around the house(s) from where farmers derive their subsistence and cash needs, and where they do not have additional land in other land use systems. Examples of such homegardens are reported from the highlands of Uganda (Odoul and Aluma, 1990) and Tanzania (Rugalema *et* al, 1994). The homegardens presented in this chapter belong to the second category.

Homegardening is widely practiced in the South and Southwestern highlands of Ethiopia. Like the other homegardens in East Africa, coffee is a dominant crop in these systems. What makes them different is the unique association of coffee with another dominant and native crop called enset. Enset (*Enset ventricosum* (Welw.) *Cheesman*), also known as false banana, is a perennial herbaceous crop and a staple food for more than 10 million people in the south and southwestern parts of Ethiopia. The enset-coffee homegardens have a complex multistorey structure where different species of crops, trees and livestock are integrated in an intimate association. While enset is the staple food, other food crops including maize, vegetables, root and tuber crops such as sweet potato and yam, pulses, fruits and other cereals are also grown. Coffee is the major cash crop, but in some areas chat (*Chata edulis*) is increasingly important as cash crop.

Trees and shrubs are very important components of homegardens, as they play multiple roles in the systems. They provide the households with wood products and cash, and also play a role in maintaining and enhancing the physical environment needed to sustain crop production. Trees provide firewood, which is the major energy source in most developing countries. Furthermore, trees provide wood for various local uses, such as housing construction, fencing, furniture, household utensils and farm tools. Trees also provide other products such as fodder, human and livestock medicine, food and they serve as bee forage. Furthermore, trees are increasingly becoming important income sources for many farmers in rural areas, mainly because the wood can be sold as timber or as firewood.

In addition to fulfilling the material needs of the farming community, trees play important ecological roles in agricultural systems. These roles include nutrient cycling, provision of mulch, nitrogen fixation (some of them), and service as shade, wind breaks and erosion control. These functions help to maintain and improve soil fertility, regulate soil moisture and temperature, and improve the microclimate eventually contributing to the stability and resilience of the systems. Therefore, the presence in farms of diverse tree species that serve different socio-economic and ecological functions could contribute to sustainability of agricultural systems.

The diversity of trees in most tropical homegardens is generally high. Many reports on homegardens indicate the total number of plant species present in the systems, and do not single out the trees. However, some reports have indicated the number of woody components which varied from 53 for Chagga homegardens (Fernandes *et* al., 1984), to 179 in West Java (Soemarwoto, 1987). The density of trees in homegardens also varied widely among and within sites. For instance, within Indonesia alone density varied between 139-160 trees ha^{-1} for Maluku (Kaya *et* al., 2002) and 1833 trees ha^{-1} for west Java (Jensen, 1993). The variation in species richness and density of trees in the different homegarden systems is related to ecological and socioeconomic conditions. For instance, homegardens in the lowland humid tropics (such as in Java) are expected to be very rich and dense in species as compared to the highlands because rainfall and temperature are very suitable. On the other hand, socioeconomic factors such as marketing could affect species richness and density because farmers focus on production of high value crops (Wiersum, 1982; Jensen, 1993). The level of household resources, such as land holding, is also expected to influence diversity and density of trees because resource poor farmers attach priority to subsistence crops for their survival.

The present study aims at characterizing the diversity of trees and shrubs in in the agroforestry homegardens of Southern Ethiopia, and analyzes the factors that influence tree diversity. More specifically, the chapter answers the questions a) what is the species richness, composition and density of trees and shrubs in these homegarden agroforestry systems? b) what is the species richness of trees at plot level, and c) which factors influence the species richness and density of individual farms?

5.2 Materials and methods

5.2.1 The study areas

The research was conducted in Sidama, which is the most populous and one of the largest administrative zones of the Southern Nations', nationalities' and Peoples' Regional State (SNNPRS) of Ethiopia. The study was carried out in 12 sites or Peasant Associations selected from four Woredas where homegardening is practised extensively (Figure 2.1). In selecting the sites, stratified sampling procedures were followed in order to represent possible local variation. First, four representative Woredas were selected out of the 10 Woredas of Sidama. Then, from each Woreda, 2-4 Peasant Associations were selected on the basis of their proximity to markets and highways, since these two variables were believed to affect diversity of trees. From each PA, 12 households were selected four from each category of economic group of farmers (poor, medium and rich) making a total of 12 households per PA and 144 households for the whole study area. Almost all the research sites are accessible by four-wheel drive cars, but most are less frequented by public transport vehicles. A major road (highway) which gives access to all sorts of vehicles crosses four of the research PAs while the remaining eight are located further away.

5.2.2 Data collection

Data were collected from 144 sample homegardens (farms). In most cases the farmers have one piece of land with a house (houses) and the gardens surrounding it. Data were collected from all farm fields that are under the control of a household. Data were collected at two levels; farm (= all farm fileds from one household) and unit. The homegardens often display a mosaic of patches or farm units which are distinct from one another because of the dominant crops grown on them. Units with similar land use were grouped as one unit type. Total area of the farm as well as area of each unit was measured and the different tree species grown in it, counted and listed using local and botanical names. For the purpose of species richness calculations, all tree and shrub species in the farms were considered. But in counting the population (individuals) of each tree species, only trees with a minimum breast-height diameter (dbh) of five centimeters were taken into account.

Fruit trees and other woody crop plants such as coffee, chat and Rhamnus (*Rhamnus prinoides*) are not included in this chapter as they are treated with crops in a separate chapter (Chapter 3). It should be noted that the homegardens stated in this chapter are equivalent to a farm system.

5.2.3 Data Analysis

Analysis of the data was carried out using quantitative and qualitative methods. To determine species richness of each farm, Species index (S), which is simply the total number of tree species on a farm was calculated. This index doesn't indicate the relative proportion or abundance of a particular species in the farm. Hence, models that incorporate both richness and the evenness of relative abundance were required. Shannon index (Shannon and Wiener, 1949) and Evenness measure (E) which are commonly used tools for these purposes (Pielou, 1969: Magurran, 1988; Huston, 1995), were calculated.

Shannon diversity index (H') is high when the relative abundance of the different species in the sample is even, and decreases when few species are more abundant than the others. It is based on the theory that when there are many species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus the diversity. It is calculated using the formula, $H' = -\sum p_i \ln p_i$ (Magurran, 1988), where p_i is the proportion of individuals composed of species i. As a measure of heterogeneity, Shannon's index takes into account the evenness of abundance of species (Peet, 1974). However, an additional measure of evenness (E), which compares the observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated. The measure of evenness (E) is the ratio of observed diversity to maximum diversity and it is calculated as, $E = H'/H_{max}, = H' / \ln S$ (Magurran, 1988). E has values between 0 and 1.0, where 1.0 represents a situation in which all species are equally abundant.

From these calculations, species richness and heterogeneity as well as density of trees were characterized for each farm. The values obtained were then statistically compared across the different site and household conditions to test for differences in species richness, species evenness and density of trees.

The above indices, which are generally referred to as alpha diversity, indicate richness and evenness of species within a locality, but they do not indicate the identity of the species and where it occurs. Hence, variation in the composition of species among the different PAs was determined by computing Beta diversity. Beta diversity (β) is usually expressed in terms of a similarity index between different habitats in the same geographical area (Huston, 1995). It is calculated using the formula, $\beta = 1 - C_j$, where C_j is Jaccard's similarity index (Magurran, 1988)

$$C_j = j/(a+b-j)$$

where j = the number of species shared by any two sites a and b,

a = the number of species in site a, and

b = the number of species in site b

The beta value varies between 0 (low diversity, sites being the same) and 1 (high diversity, sites being completely different).

Four prototypes of the enset - coffee homegarden agroforestry systems were identified on the basis of the composition of major crops (Chapter 3). Tree species richness and evenness as well as tree density of farms were compared among these prototypes. The variation in species composition among the farms was described using Detrended Correspondence Analysis (DCA). Specific attention was given to differences between the four prototypes.

The effects of physical and socioeconomic environments on the diversity indices were determined through multiple linear regression analysis. A separate multiple regression model was used for each index. Thus each model included a number of independent variables (of the local and household characteristics) and one of the dependent variables. The indices included species richness (S), Shannon index (H'), Measure of evenness (E), density of trees per farm and density of trees per hectare. The effect of distance between sites on beta diversity was analyzed using linear regression.

5.3 Results

5.3.1 Species diversity

In total 120 tree- and shrub-species were recorded in the homegarden agroforestry systems of Sidama, (Appendix 5.1). Frequency of occurrence of the species across homegardens was rather variable (Figure 5.1), but six species occurred in over 100 out of the 144 homegardens. *Cordia africana* was the most frequent species occurring in 98% of the farms. It is followed by *Eucalyptus camaldulensis* (95%), *Milletia feruginea* (88%), *Euphorbia candelabrum* (88%), *Cupressus lusitanica* (77%) and *Podocarpus falcatus* (70%). On the other hand, 12 tree species were very rare each occurring only in one of the farms. Out of the total number of species, only 17% were exotic while the remaining 83% were indigenous. The number of species varied across Woredas (F-test, P<0.001) and Peasant Associations (F-test, P<0.001). The total number of species per Woreda varied from 51 at Awassa Zurya to 97 at Aleta Wondo (Table 5.1). Aleta Wondo, with 82% of the total number of species in the study sites was the richest at Woreda level. At farm level, the average number of tree species was 20.7 but the Woreda averages varied from 12.2 for farms in Awassa zurya to 24.1 for farms in Dale.

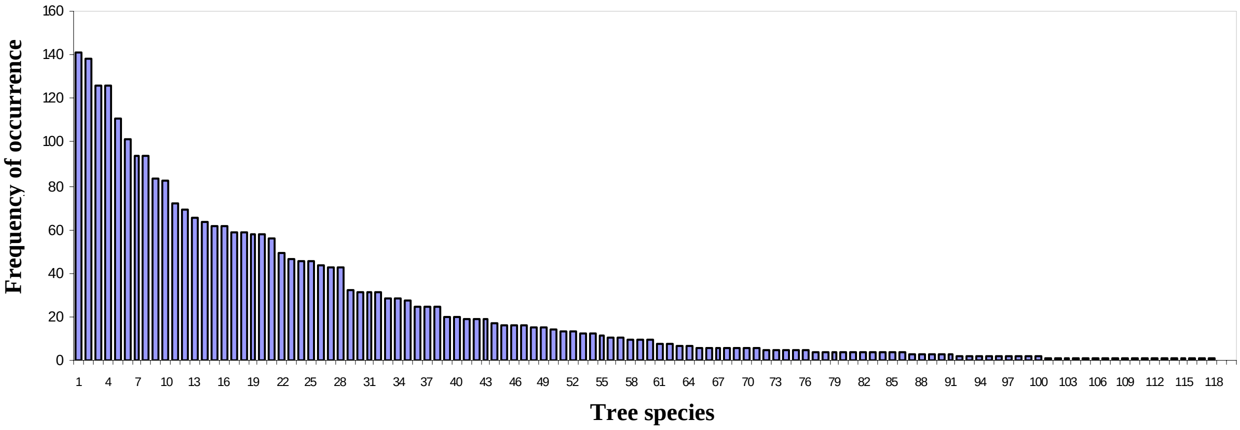

Figure 5.1 Frequency distribution of the three species across the farms (n=144).

Table 5.1 Number of tree species per farm at Woreda level.

Woreda	Number of tree species		
	Total	Mean per farm	Standard deviation
Dara (n=36)	82	20.8 [a]	9.7
Aleta Wondo (n=48)	97	22.5 [a]	11.4
Dale (n=36)	94	24.1 [a]	9.3
Awassa Zurya (n=24)	51	12.2 [b]	4.8
Total (n = 144)	120	20.7	9.8

The diversity and density of tree species also varied across the site (PA) levels (Table 5.2). Among the PAs, Belesto, from Aleta Wondo Woreda had the highest number of species (72) accounting for 61% of the total number. Farm level species richness is also highest at the same PA. Here, the average number of tree species per farm was 33.4. Only one farm in this PA had 55 species and it contributed to 47% the total species in the study areas. The minimum number of species per farm was 4 at Tesso where the PA average was also low (14). Farms in Chefasine and Abela Tula, both from Awassa Zurya Woreda had the lowest average species number of 11.5 and 12.8, respectively.

Table 5.2 Tree diversity of farms at the Research sites (PAs). In each PA 12 farms were analysed.

Site (PA)	Number of tree species			Number of trees		Shannon's index (H')	Evenness (E)
	Total	Mean	SD	per farm	per ha		
Setamo	52	19.7 ^{cd}	8.9	528 ^{b}	309 ^{bc}	1.62 ^{ab}	0.58 ^{ab}
Shoyicho	66	28.4 ^{ab}	9.6	912 ^{b}	592 ^{abc}	1.49 ^{ab}	0.46 ^{abc}
Qumato	31	14.2 ^{de}	4.2	187 ^{b}	113 ^{c}	1.21 ^{bc}	0.47 ^{abc}
Belesto	72	33.4 ^{a}	13.8	3791 ^{a}	1081 ^{a}	1.53 ^{ab}	0.46 ^{abc}
Lela Honcho	52	19.7 ^{cd}	5.0	442 ^{b}	315 ^{bc}	1.48 ^{ab}	0.51 ^{abc}
Tesso	58	14.0 ^{de}	6.7	125 ^{b}	86 ^{c}	1.60 ^{ab}	0.64 ^{a}
Sheyicha	62	22.9 ^{bc}	8.6	1699 ^{b}	728 ^{ab}	1.29 ^{bc}	0.43 ^{bc}
Ferro I	66	28.5 ^{ab}	7.4	729 ^{b}	347 ^{bc}	1.88 ^{a}	0.58 ^{ab}
Ferro II	58	18.2 ^{cde}	7.2	559 ^{b}	1082 ^{a}	1.27 ^{bc}	0.46 ^{abc}
Tula Aposto	69	25.3 ^{bc}	9.6	572 ^{b}	454 ^{bc}	1.21 ^{bc}	0.39 ^{c}
Chefasine	32	11.5 ^{e}	4.3	401 ^{b}	398 ^{bc}	0.86 ^{c}	0.37 ^{c}
Abela Tula	43	12.8 ^{de}	5.3	312 ^{b}	198 ^{bc}	1.44 ^{ab}	0.59 ^{ab}
Total (n=144)	120	20.7	10.3	855	475	1.41	0.50
F-test (P)		<0.001		<0.05	<0.001	<0.01	<0.05

Shannon's index of diversity showed mean value 1.41, while the measure of evenness (E) was 0.50. This means the relative homogeneity of the species in the samples is 50% of the maximum possible even population. Some species are thus more abundant than others. Species evenness varied between 0.37 and 0.64. Shannon value progressed from a minimum of 0.86 at Chefasine to a maximum of 1.88 at Ferro I. However, the pattern of Evenness (E) values did not always correspond with Shannon values. If we take the above two PAs for instance, the lowest evenness value (0.37) was at Chefasine, but the maximum (0.64) was at Tesso and not at Ferro1. Tesso, with a low average species richness of 14.0 had the maximum evenness value, because of better representation of few species. Farms in Ferro 1 had the highest Shannon index because the mean total number of species is among the highest (28.5) and the commonly occurring species are represented by many individuals. Moreover, the minimum number of species per farm was 16 indicating that this PA is generally more diverse in tree species as compared to the others.

The average number of trees per farm and per hectare varied widely among the sites, with mean values of 855 and 475 respectively. The number of tree species, total number of individual trees as well as the number of trees per hectare increased with increasing farm size.

5.3.2 Importance of selected tree species

It was indicated that a total of 120 tree species were recorded in the homegardens of Sidama, but some trees are more common occurring in most of the farms, while others are rare. Likewise, the low values of evenness indices have indicated that among the species occurring at a site some are more abundant than the others. Four tree species, namely *E. camaldulensis, C. africana, M. ferruginea* and *P. falcatus* are the most common in terms of their occurrence and abundance in the farms. Together they accounted for 61% of all individuals (Figure 5.2). *E. camaldulensis* alone accounted for an average of 45% of the tree population in the farms. The remaining 116 tree species represented only 39% of the individuals. Because of the wide importance attached to the four tree species in the region, their management aspects and major roles are separately presented here.

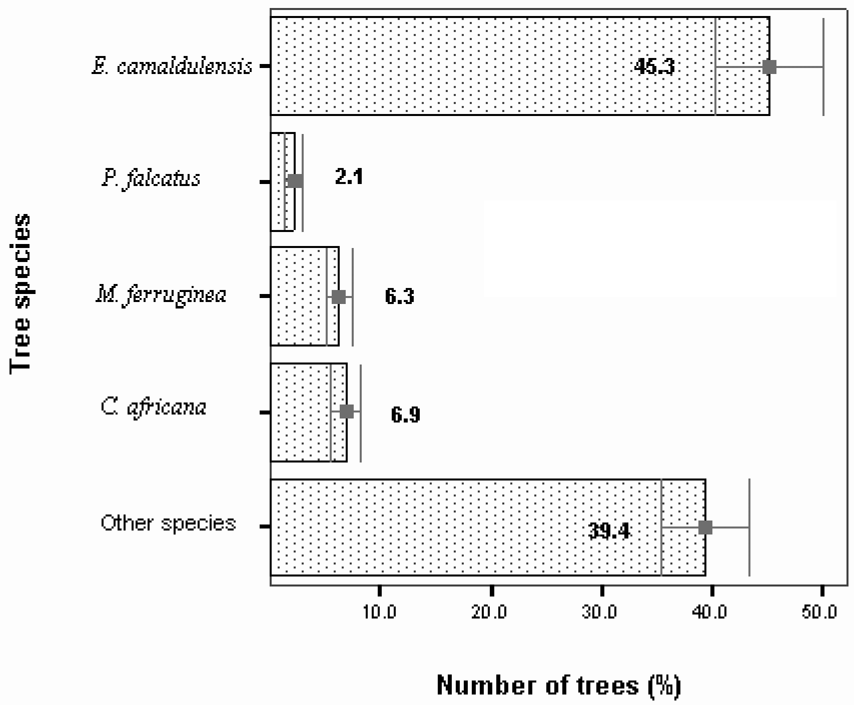

Figure 5.2 Mean proportional abundanceof the common tree species. Error Bars show 95.0% CI of Mean.

Eucalyptus camaldulensis

E. camaldulensis is present in 95% of the farms, and it consisted of 30 to 64% of the tree population at the sites, with an average of 45%. The tree is increasingly becoming an important cash crop because of its long and slim posts and split wood which are highly demanded for housing construction in rural as well as urban areas. The tree is often grown in short rotations of 3 to 8 years. Farmers have adapted a system of high density planting to reduce excessive branching and encourage the development of upright single stems. Planting density of 10000 to 15000 trees ha^{-1} of 3-5 year old eucalyptus were observed during the farm visits. The high density and high proportion of eucalyptus in the study areas have definitely contributed to the overall high total number of trees.

On the other hand, farmers clearly understand the competitive effects of the tree and they do not grow it with crops. During the field visits, there was no single observation where eucalyptus was grown inside crop fields. In farms with a large population of eucalyptus, farmers allocated a block of land (woodlot) on the periphery of their farm, or on water logging parts when available, to grow this tree. When the population is small, it is grown alongside farm boundaries, often on the boundaries adjacent to the road. Planting of eucalyptus on boundaries adjoining crop fields of other farmers is carried out only with the consent of the neighboring farmers. In general, more farmers in Sidama are motivated to plant the tree because of its high cash return, but they plant it in such a way that it doesn't compete directly with agricultural crops.

Cordia africana

C. africana is the most frequent species with occurrence on 98% of the farms. It represented an average of 6.9% of the tree population in the farms. The tree grows to a height of 25 meters and most of the mature trees had a diameter (Dbh) of 60-80 centimeters, but one tree with a diameter of 200 centimeters was measured. *C. africana* is popular among farmers because they regard it as complimentary to agricultural crops and provider of multiple benefits. The functions of the tree include provision of shade and mulch for the integrated enset-coffee systems resulting in control of soil erosion, regulation of soil moisture and temperature, improved soil nutrition, eventually creating favorable conditions for crop growth. To reduce excessive shading, farmers lop or pollard the branches, and use the wood for different purposes. The wood produces durable timber that is used for the manufacture of furniture, doors, beehives, farm tools and household utensils such as trays and mortars. Besides its use in local manufactures, the wood is also sold to wood processing and furniture factories in towns and thus it contributes to income generation. In addition to the above-mentioned uses, the wood is used for fuel, the flower is important bee forage, the fruit is edible and the bark is used for medicinal purposes.

Milletia ferruginea

M. ferruginea is another fast growing native leguminous tree species common in the study areas. It occurred in 88% of the farms and contributed to an average of 6.3% of the tree population in the farms. Most trees in the farms have heights of about 15-30 meters and a diameter of 10 to 60 centimeters. However, at farms occurring within the upper altitudinal ranges of these agroforestry systems (1900-2000 meters a.s.l.), old trees that reach a height of 30 meters and a diameter of 140 centimeters were measured. *M. ferruginea* is an important shade tree in these homegardens where it provides mulch and protection to the understorey. The tree produces poles for local construction and for the manufacture of tool handles. The wood is also used for fuel. Its pounded seeds are used as fish poisons, to stun fishes in freshwater streams during fishing.

Podocarpus falcatus

P. falcatus, commonly called East African yellow wood, is a giant indigenous species that is widely grown in the study areas. It occurred in 70% of the farms and contributed to 2.1% of the tree population in these homegardens. Although its population is relatively small, the standing stock of this tree is high because of the presence of mature trees in many farms (Chapter 6). *P. falcatus* is popular for its excellent timber that is used for furniture, paneling and other purposes. In most cases, *P. falcatus* trees grown in the farms have a height of 15 to 25 meters and a diameter of 20-60 centimeters. However, old giant trees with a height of 30 meters and a diameter of 220 centimeters were measured. The tree grows even larger. Pankhurst (2000) has reported the presence of a revered *P. falcatus* tree (locally named 'Awliyaw') in the Anabe forest of South Wollo in Northen Ethiopia, which has a diameter of 400 centimeters and an estimated height of 63 meters.

Farmers in the study area often grow the podo tree scattered in the front yards. The front yards are used as grazing areas, as meeting places during cultural ceremonies such as weddings or funerals, and also as burial places. The tree is also grown alongside farm boundaries and in blocks, but rarely grown scattered in the crop fields. Almost all the timber that is used for furniture and paneling works in the urban and rural areas of Sidama comes from farms, with *P. falcatus* contributing the largest share.

5.3.3 Diversity of trees in farm units

It was indicated earlier that although these homegardens are generally integrated multistorey systems, there are patches or units in the systems that can be distinguished from one another by the dominant crop. The size of the unit types varied among sites and households depending on socioeconomic factors such as land holding and market access. Despite this variation, coffee and enset units are the most dominant ones accounting for 63% of the crop fields (Chapter 3).

Tree species richness of the different units varied widely (Figure 5.3). The coffee units, which cover large proportion of the farms, are the richest in tree species (13.3) while units that represent only a small portion of the farms such as pineapple, chat and sugarcane have the lowest number of tree species. Although the chances of getting more species could increase with size of the plots, deliberate planting and management also occurs. Coffee units, even when small, are rich in species but plots of pineapple, chat, sweet potato and maize of any dimension always have few tree species or no trees at all because the crops require more light.

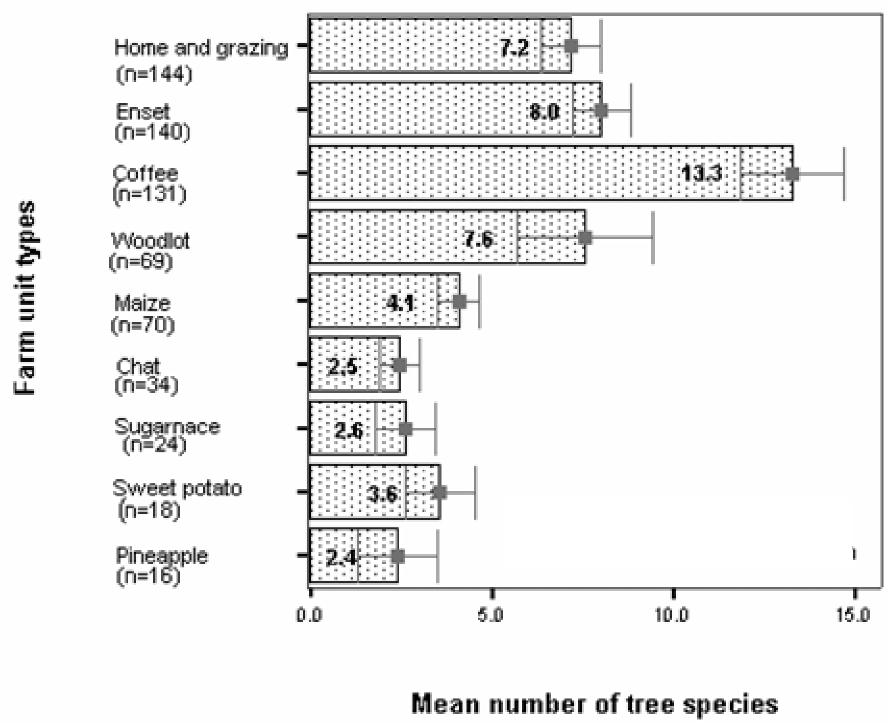

Figure 5.2 Mean number of tree species associated with the different unit types. Error Bars show 95% CI of Mean.

Enset units are also rich in species. The average (8.0) is lower because young enset, before final transplanting, is often grown in high densities and then only few associated crops and trees can come in. The home and grazing units include the homestead and its front yard which is used for grazing, and sometimes other grazing lands within the farm. In the front yards, widely spaced shade trees are maintained to allow sufficient light for good growth of grass. In many cases, old and giant *P. falcatus* or other native species are found scattered in these units. Boundaries of the front yards, which are often boundaries of the farm, are planted with live fences of *Euphorbia candelabrum* or *Cupressus lusitanica* trees, and closely spaced rows of eucalyptus and sometimes Podocarpus trees. The density of trees along the boundaries is high but the number of species is small.

The woodlots (tree units) have an average of only 7.6 species, against the expectation that a plot composed of only trees could be the richest in species. This is mainly due to the fact that most woodlots are dominated by eucalyptus. Out of the sample farmers, 44% had separate plots for trees. Among these, 31% have allotted 1 to 10 % of their land to trees, 11% have it on 10-20% of their land and the remaining 2% have allotted more than 20% of their land to trees. The largest number of 40 tree species in a tree unit was found in a unit composed of remnants of the natural forest.

5.3.4 Composition of trees species across the sites

The composition of tree species between the sites varied between 25 to 75% (Table 5.3). The least difference in species composition (25%) was observed between the two closely located PAs of Belesto and Sheyicha in Aleta Wondo Woreda, which are similar in altitude, rainfall and cropping patterns. On the other hand, the composition of trees at Belesto and Qomato PAs differed by 75%. The tree composition in the low altitude PAs of Qomato and Tesso differed from the rest by an average of more than 70 and 60% respectively. Altitude and geographical distance have effects on the dissimilarity of tree species across the sites. Dissimilarity in the composition of tree species increased with increasing geographical distance and elevation difference (Figure 5.4).

Table 5.3 Beta diversity (dissimilarities in composition) of tree species across the sites (1= very dissimilar, 0= very similar).

Sites (PAs)	Setamo	Shoyicho	Qumato	Belesto	Lela Honcho	Tesso	Sheyicha	Ferro 1	Ferro 2	Tula Aposto	Chefasine	Abela Tula
Setamo	-	0.40	0.67	0.38	0.38	0.62	0.32	0.42	0.37	0.56	0.63	0.64
Shoyicho		-	0.68	0.40	0.36	0.59	0.32	0.41	0.42	0.50	0.64	0.62
Qumato			-	0.75	0.65	0.65	0.71	0.71	0.69	0.69	0.63	0.70
Belesto				-	0.39	0.58	0.25	0.37	0.40	0.51	0.64	0.57
Lela Honcho					-	0.59	0.31	0.34	0.33	0.57	0.56	0.59
Tesso						-	0.61	0.62	0.63	0.48	0.67	0.59
Sheyicha							-	0.32	0.35	0.53	0.61	0.58
Ferro 1								-	0.32	0.50	0.64	0.53
Ferro 2									-	0.53	0.63	0.55
Tula Aposto										-	0.67	0.49
Chefasine											-	0.41
Abela tula												-

Tree species richness and heterogeneity as well as number of individual trees varied across the different prototypes of the enset-coffee homegardens (Table 5.4). In the subsistence oriented enset-coffee-maize-sweet potato systems, homegardens have the highest number of tree species (25.3) but evenness was among the lowest. The original type enset-coffee-maize sub-systems have the highest density of trees (636 trees ha^{-1}), the second highest number of species (20.1) and species evenness values were among the highest. The remaining two cash crop oriented systems have the lowest number of tree species and tree density. Among them, the density of trees in the enset-coffee-maize-chat-pineapple systems was the lowest (100 trees ha^{-1}).

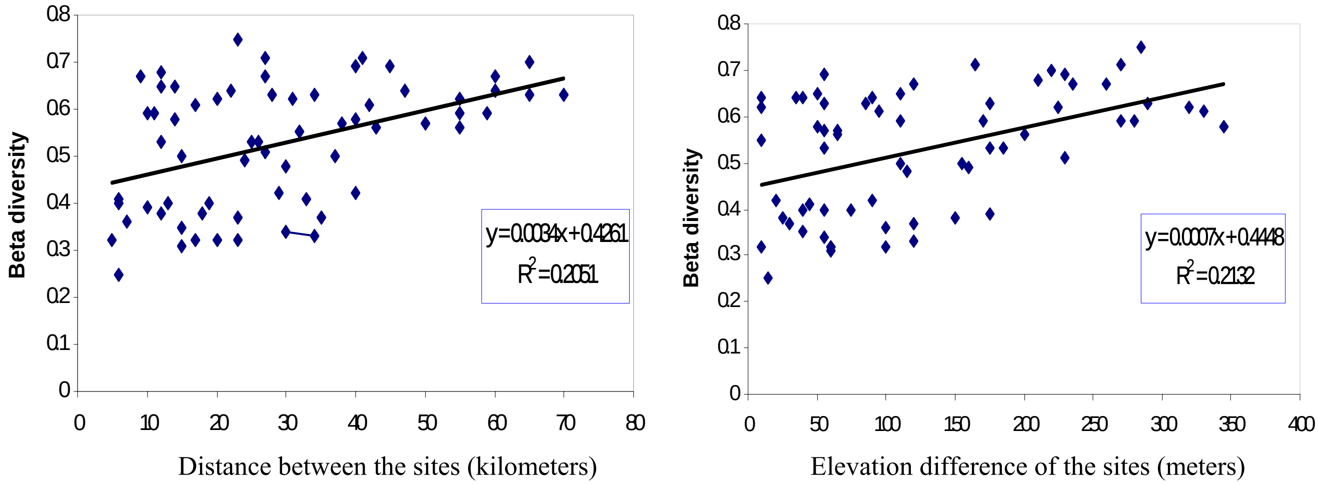

Figure 5.4 Dissimilarities in composition of tree species (beta diversity) in relation to altitudinal difference and geographical difference of the sites (n=66). Each data point is a couple of two sites. The data derive from Table5.3.

Spatial relationships between the tree species and the sites showed a distinct association of tree species along with the different prototypes. In order to determine the major gradients in species composition among homegardens, the data from the 144 homegardens were summarized using Detrended Correspondence Analysis (DCA). Four clusters can be distinguished that relate to the prototypes (Figure 5.5) indicating that the composition of tree species in each of the prototypes show great similarity.

Table 5.4 Mean values of Species richness, Shannon and Evenness indices and density of trees at the different prototypes of the enset-coffee agroforestry homegardens

Prototypes	**Mean nr. of tree species per farm**	**Shannon index (H')**	**Evenness index (E)**	**Number of trees per farm**	**per ha.**
A. Enset-coffee-maize (n=84)	24.4 [a]	1.51 [a]	0.50 [ab]	776 [a]	636 [a]
B. Enset-coffee-maize-chat (n=24)	12.2 [b]	1.15 [a]	0.48 [ab]	357 [ab]	298 [ab]
C. Enset-coffee-maize-sweet potato (n=12)	25.3 [a]	1.21 [a]	0.39 [b]	572 [ab]	454 [ab]
D. Enset-coffee-maize-chat-pineapple (n=24)	14.1 [b]	1.41 [a]	0.55 [a]	156 [b]	100 [b]
Mean (n=144)	20.7	1.41	0.50	855	475
F-test	P <0.001	P<0.05	n.s.	P<0.05	P <0.001

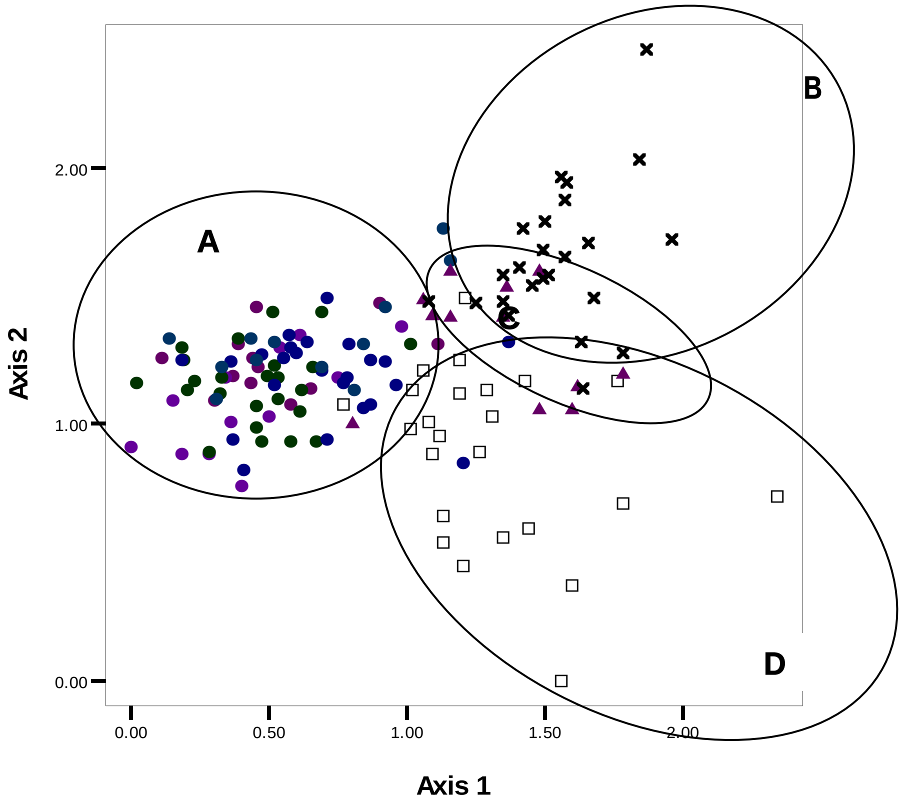

Figure 5.5 Detrended Correspondence Analysis (DCA) scatter plots of the tree composition of the farms (n=144).

Key:

● = homegardens in the enset-coffee-maize prototype which are clustered in 'A'
× = homegardens in enset-coffee-maize-chat prototype clustered in 'B'
▲ = homegardens in enset-coffee-maize-sweet potato prototype clustered in 'C'
□ = homegardens in enset-coffee-maize-chat-pineapple-sweetpotato prototype clustered in 'D'.

5.3.5 What factors influence diversity and density of trees in the homegardens?

Some physical and socioeconomic factors influence farm level species richness and density of trees (Table 5.5). Farms located near roads had a lower number of tree species, and lower diversity. The number of trees per farm and per hectare increased with distance to major roads, suggesting that further from the roads farms are less exploited. Also species evenness decreased with distance from the roads. Within the altitudinal limits (1520-2040m a.s.l.), the total number of trees as well as their density increased with altitude. Although all sites are within the same agroecological zone the lower areas are warmer and this could result in higher evapo-transpiration and lower available moisture. Assuming the same amount of total rainfall, the availability of moisture for plant establishment and growth increases with altitude, and so a higher tree density can be maintained without a negative effect on crop growth.

Table 5.5 Multiple stepwise linear regression of tree diversity and density indices with Physical and socioeconomic factors. Values indicate standardized Beta coefficients.

Factors	**Species richness (S)**	**Nr. of trees per farm**	**Nr. of trees ha^{-1}**	**Shannon's index (H')**	**Evenness (E)**
Model (Adjusted R^2)	**0.53*** **	**0.46*** **	**0.26*** **	**0.20*** **	**0.23*** **
Physical environment					
- Altitude of the farm	ns	0.15*	0.24**	ns	ns
- Slope of the farm	0.15*	ns	ns	ns	ns
Socio economic environment					
- Distance to markets	ns	ns	ns	ns	ns
- Distance to major roads	0.27***	0.19*	0.22**	0.22**	ns
- Farm size	0.40***	0.39***	ns	ns	ns
- Area of woodlot	0.14*	0.40***	0.41***	-0.46***	-0.40***
- Farm labour force	ns	ns	ns	ns	ns
- Involvement in off-farm activities	0.14*	ns	ns	ns	ns

Note: ns = not significant; *, **, *** = Significant (F-test) at p<0.05, p<0.01, p< 0.001, respectively.

Tree species richness increased with slope. This can possibly be attributed to the presence of additional niches such as swampy areas at the bottom of the slope often covered with bamboo or eucalyptus, or the presence of steep slopes that require certain trees or shrubs for effective soil conservation. The range in distances from farm to market was large enough (0.4-6 km) to affect transport of goods, but this factor did not have any effect on the diversity and density of trees.

The labor resource of the sample households increased from a mean of 3.7 for the poor farmers to 5.0 and 6.4 for the medium and rich farmers, respectively. However, the variation in labor resource did not have any influence on diversity and density of trees. About 30% of the farmers, or members of their family, involve in off-farm activities. The duration of engagement varies from a few days to some months per year. Involvement in such activities had no significant effects on tree species richness of farms. This indicates that farm labor force, which can potentially decrease due to involvement in off-farm activities, is not in short supply to plant or manage trees.

Other factors expected to influence diversity of tree species in farms are economic status and ethnic background of the households. Economic status in itself did not influence tree diversity. However, as the economic status of farmers is highly correlated with farm size (r=0.72), the variation among different economic groups is explained by the farm size. As regards to ethnicity, the ethnic composition of the sample households is dominated by the Sidama, which constituted 93% of the households. The sample size from the other groups is not large enough to make statistical comparisons, but our observation was that ethnic background of farmers did not influence diversity and density of trees.

5.4 Discussion

5.4.1 Species richness and evenness of trees

The large number of tree and shrub species recorded in the homegardens of Sidama, (120) puts them among the agroecosystems that are very rich in tree species. Earlier studies on tree species richness of homegardens have reported 53 woody species for Chagga homegardens in Tanzania (Fernandes *et* al., 1984), 69 for the compound farms of Nigeria (Okafor and Fernandes, 1987), 77 for Kandy in Srilanka (Perera and Rajapakse, 1990), 83 for Nicaragua (Mendez *et* al., 2001), 129 for Kerala in India (Kumar *et* al., 1994), 168 for Peruvian Amazon (Padoch and Jong, 1991) and 179 for West Java (Soemarwoto, 1987). The number of tree species in Sidama homegardens exceeds most of these figures. The figure is particularly very high when compared to the similar highland agroecosystems of the Chagga homegardens. Moreover, most of the above reports have considered all woody plants including fruit trees and ornamentals, which are not included in the present study. A total of 21 woody crop plants (fruit trees, coffee, chat and others) were recorded in these homegardens but they are not included here since they are treated separately as crops. Hence, if all woody plants were taken into account, the total number of species in these systems would be comparable to the highest reported figures.

The mean number of tree species per farm was 21, with 88% of the farms having more than 10 tree species, the maximum being 55. This figures are in line with reports from Kerala homegardens which was 11 to 39 tree species (Kumar *et* al., 1994) and Rwanda, 12 to 34 (Biggelaar and Gold, 1996). The high number of tree species in the homegardens, 83% of which are native to the region, indicates the significant role of these systems in the conservation of genetic diversity, as reported in homegarden studies in other regions (Michon, *et* al., 1983; Alvarez-Byulla Roces *et* al., 1989, Soemarwoto and Conway, 1991; Kessy, 1998). The trees serve several functions. They provide firewood, timber, wood for different purposes (local construction, farm implements, household utensils), fodder, food, medicine, and they also play beneficial ecological roles such as erosion control and soil fertility improvement (Appendix 1). The presence of many tree species and shrubs of different uses contributes to the diversification of tree products and sustenance of agricultural systems.

The diversity indices for tree species generally showed that few species are more abundant than the others. The mean evenness (E) values of 0.37 to 0.64 indicated dominance of some tree species. On the whole, evenness of tree species was 50% of what it could have been under uniform distribution. Such a distribution is expected in agroecosystems, since farmers could have preferences for more valuable species. In the Sidama homegardens only four of such popular species have constituted 61% of the total tree population.

The evenness values obtained here are comparable to values reported by Kumar *et* al. (1994) for the homegardens of Kerala where Evenness values ranged from 0.24 to 0.71. Kaya *et* al. (2002), have reported high Evenness values of 0.71 to 0.91 for the forest gardens of Central Maluku, Indonesia, but the sampling methodologies employed were different.

5.4.2 Importance of selected tree species

The most important tree species in these systems are *E. camaldulensis, C. africana, M. ferruginea* and *P. falcatus*. They are common and abundant because of their wide economic and ecological roles in the systems. All, except *E. camaldulensis*, are native to the areas, where they widely occur in the remnants of the natural forests. It appears that farmers have selectively maintained more of these species in the process of transformation of the forests to homegardens. Farmers encourage natural regeneration of these species, plant wildlings, and in some cases they propagate the seedlings. *E. camaldulensis* grows fast and produces posts and split wood that are highly demanded for housing construction. It is therefore an important cash crop for the farmers. The popularity of eucalyptus among farmers is also reported for the agroforestry systems of Rwanda, where it makes up about half the tree population irrespective of the farm size (den Biggelaar and Gold, 1996).

C. africana is a very important shade tree in these homegardens. Farmers believe that it improves soil fertility and hence they grow it in a large number. Demel Teketay and Assefa Tegineh (1991) have also reported the popularity of this tree as an important coffee shade in Eastern Ethiopia. Moreover, *C. africana* has a good quality timber that is widely marketed in urban areas. Thus the socioeconomic and ecological benefits of the tree have made it popular among farmers. *C. africana* is one of the fast growing native tree species (Legesse Negash, 1995; Tesfaye Abebe, 2000), but it often has short and twisted stems, and this limits its timber value. However, provenances which have long straight boles of up to 12 meters were observed in some farms in Dara and Aleta Wondo Woredas. Hence, improvements in its timber quality, and consequently on farmers' income, can be made by selecting appropriate provenances.

M. ferruginea is a popular shade tree in these systems. In a study carried out to determine the impact of *M. ferruginea* on soil fertility and growth of maize, Hailu *et* al (2000) have found that the surface soils from under canopy of *M. ferruginea* trees had significantly higher nutrient levels than the open fields. This could explain why farmers widely grow the trees in their farms.

P. falcatus is a popular timber producing species. Almost all the timber that is used for furniture and panelling works in the urban and rural areas of Sidama comes from farms, with *P. falcatus* contributing the largest share. Culturally, the Sidama have a high respect for the podo tree. The presence of some well-protected and respected sacred groves, locally called *Gudumale*, which are composed of giant podo trees, is just an indicator of such a respect. One of the problems with this tree is its poor germination capacity. Farmers often collect wildings for planting or they protect naturally regenerated seedlings. Recent research endeavors on in-vitro propagation techniques of this tree (Legesse Negash, 1995), have shown promising results that might contribute towards the maintenance and reproduction of the podo tree.

5.4.3 Density of trees

The density of trees per hectare ranged from 86 to 1082 with an average of 475. The high density of trees in some farms is attributed to trees (mainly Eucalyptus) planted at very high densities on boundaries and in block arrangements. In some farms dense live fences of *Euphorbia candelabrum* and *Cupressus lusitanica* are found. Eucalyptus is harvested in short rotations for its long and slender posts, and thus it is grown in high densities. On the other hand, trees dispersed in the farms generally have low densities in order to reduce competition with agricultural crops. The high density of trees in Sidama homegardens is in agreement with earlier reports from other regions. In the Kandyan gardens of Sri Lanka, Perera and Rajapaske (1991) have reported that the number of trees with a diameter of 5 centimeters and above was 92-3736 trees ha^{-1} with 70% containing 500-1500 trees ha^{-1}. Jacob and Alles (1987) have also reported tree density of 65-1700 ha^{-1}. In the highlands of Rwanda, where ecological and demographic factors are more or less similar to the study area, an average density of 731-1689 trees ha^{-1} was reported (Biggelaar and Gold, 1996).

5.4.4 Diversity of trees in farm units

The homegardens of Sidama are characterized by the presence of units or patches. Such patch formations in homegardens have also been reported by Mendez *et* al (2001) who used the term 'micro-zones' to describe the patches (units). The dominant coffee and enset units together with home and grazing lands cover about 80% of the farm areas. The remaining 20% of the areas is composed of other patches of crops of which maize takes a share of about 10%. Nevertheless, due to the huge dominance of the integrated coffee-enset units in relation to small size of the farms, the multistorey structure is evident, and hence the term homegarden. In addition to their coverage of large areas, which could increase the chance of getting more species, the coffee and enset units are rich in tree species because a lot of trees are used as shade. On the other hand, units composed of maize, chat and pineapple are poor in number of tree species, since shade trees are deliberately reduced or avoided.

5.4.5 Variation in composition of trees species among sites

There are basic sets of tree species that are common in the homegardens of Sidama, but differences occur in composition of the species among sites. The variation is mainly attributed to differences in altitude, farmsize and the distance to roads. The altitudinal difference (1520 to 2040 m.a.s.l.) is large enough to show differences in the composition of natural vegetation. For instance, in the low lying and relatively warmer and drier sites, dryland species such as *Faurea rochetiana* and *Combretum molle* are common but these species are absent in the higher altitudes. On the other hand, tree species such as *Ocotea kenyenis*, *Olea capensis, Polyscias fulva* and *Erythrina spp.* that are common in the higher altitudes are very rare in the lower sites. These variations reflect ecological adaptations of the species to particular sites. Likewise, the composition of some native timber species such as *Ekbergia capensis, Syzigium guineense* and *Olea capensis* near highways is very low, due to intensive exploitation.

Comparison of the diversity indices among the four prototypes of the enset-coffee homegarden systems indicated a clear difference in tree species richness and evenness, and density of trees between the widely occurring enset-coffee-maize systems and the other derivatives. Tree species richness and evenness, as well as density of trees decreased in the systems where the composition of the basic crops, enset and coffee, decreased due to an increased share of other cash and food crops.

The composition of tree species is related to the differences in the crop composition of the prototypes of the homegardens. For instance, in the enset-coffee-maize prototypes where little change has taken place in landuse, the composition of trees is similar. Likewise, in each of the other three prototypes where the area share of major crops has been altered, the composition of trees is similar. Due to a combination of factors such as altitude, geographical location and road access, the sites have evolved into distinct land use types which are not only characterized by the composition of the major crops but also by the composition of tree species.

5.4.6 What factors influence the diversity and density of trees in farms?

Diversity and density of trees are variable among research sites and households within a site, mainly due to local socioeconomic and physical conditions. The most important of these factors are farm size, area of woodlots, proximity to major roads (highways) and altitude.

Larger farms had more trees and more tree species. This is because farmers who are constrained by shortage of land concentrate on fewer species of greater utility and allocate more of their land to food crops, while large holders can afford to include different types of trees. The pattern of increasing tree species richness with increasing land holding was also reported for other homegarden systems (Kumar *et* al., 1994; Biggelaar and Gold, 1996; Mendez *et* al., 2001). Farm size did not affect the density of trees. This contradicts with earlier reports (Nair and Sreeharan, 1986; Kumar *et* al., 1994; Biggelaar and Gold, 1996) who found that density of trees declined with increasing land holding. The large share of densely stocked eucalyptus in these farms could have contributed to high overall density of trees.

With increasing areas of woodlots, the number of tree species as well as the total population and density of trees increased, but the evenness of the tree population decreased significantly. Area of woodlot is highly correlated ($r=0.41$) with the proportion of eucalyptus, and eucalyptus is often planted in high density to be harvested in a short rotation cycle of 3-8 years. Therefore, densely stocked eucalyptus trees that dominate the woodlots have contributed to the increase in density of trees. On the other hand, the high dominance of eucalyptus in the woodlots resulted in a highly uneven population of trees leading to a low evenness value. Thus, while species richness is heavily influenced by farm size, the density of trees is heavily associated with the size of woodlots.

Distance of a farm to major roads influences tree species richness and heterogeneity as well as density of trees. The closer the farm is to a road, the fewer the number of tree species, the more uneven in abundance of the species and the lower the density of trees. The presence of major roads has increased market access for the farmers living in the surroundings. Wood products from the farms are sold on the roadside or are transported to markets in big towns. Products such as firewood, construction poles and posts, and sawnwood are largely sold to traders who transport them by trucks to urban areas. Thus, proximity to roads has given a better market access to wood products than the physical proximity to local markets. Increased marketing of wood products results in more intensive exploitation of trees in the farms, and this could lead to reduced diversity and density of trees in homegardens located close to the roads. Tree planting is often carried out with fast growing and highly demanded species, mainly eucalyptus, and this dominance affects the homogeneity of tree species. Such effects of road access on the diversity and homogeneity of trees has also been reported elsewhere (Kaya *et* al., 2002).

5.5 Conclusions

The enset-coffee homegarden agroforestry systems of Sidama are rich in tree species. A total of 120 species of trees and shrubs are found in the systems, excluding woody crop plants such as fruit trees and coffee. On average, each farm had 21 species of trees and shrubs, but species richness increased with farm size. An average number of 475 trees is grown per hectare of land holding. However, the density of trees largely depended on the planting pattern and composition of the trees. Farmers who have separate woodlots of trees grow a high density of up to 4500 trees ha^{-1} with eucalyptus as the dominant component, but trees grown scattered in crop fields have a low density. Only four tree species, namely E. *camaldulensis, C. africana, M. ferruginea* and *P. falcatus* accounted for 61% of the tree population resulting in lower evenness. The dominance of these species is due to their higher socioeconomic and or ecological roles in the farming systems. Differences exist in the diversity and composition of tree species in the systems across the sites and among households within a site. Socioeconomic factors, mainly road access which increased marketing opportunities, farm size and area of woodlots, and physical factors particularly altitude are responsible for the variation in species richness and heterogeneity, species composition and density of trees. In the sites where the two basic crops, enset and coffee constitute 70-80% of the farm land, the diversity and density of trees is generally high. However, in the sites where the share of these basic crops declined due to introduction of other cash crops, the diversity and density of trees is lower. This indicates that increased commercialization of crop products affects not only the land use but also the diversity and composition of trees.

Appendix 5.1 List of tree and shrub species found in the enset-coffee homegarden agroforestry systems of Sidama

Nr.	Botanical name	Vernacular names		Family	Frequency	Origin	Local uses
		Sidama	*Amharic*		(%)		
1	*Acacia abyssinica* Benth.	Wacho	Grar	Mimosaceae	8	I	Bf,Fd,Fi,Ft,Po,Sc,Sh
2	*Acacia mearnsii* de Wild. Syn. *A. mollisima* auct.			Mimosaceae	3	E	Bf,Fd,Fi,Po,Sc,Sh,
3	*Acacia saligna* (Labill.) syn. *A. cyanophylla* Lindl.	Akacha	Akacha	Mimosaceae	3	E	Fd,Fi,Po,Sc,Sh
4	*Acokanthera schimperi* (DC.) Oliv.	Qerâru		Apocynaceae	9	I	Fi,Md,Sh
5	*Albizzia gummifera* (J.F.Gmel.) C.A. Sm.	Mâtticho	Sessa	Mimosaceae	45	I	Bf,Fd,Fi,Hu,Md,Sc,Sh,Ti
6	*Allophylus abyssinicus* (Hochst.) Radlk.	Sakaru		Sapindaceae	1	I	Fi,Ft,Po,Sc,Sh
7	*Aninigeria altissima* (A. Chev.) Aubrev. & Pellegr.	Dugucho		Sapotaceae	6	I	Fi,Sc,Ti
8	*Apodytes dimidiata* E. Mey. Ex Benth.	Dongicho		Icacinaceae	13	I	Fi,Po,Sh,Ti,
9	*Arundinaria alpina* K.Schum.	Lêmmicho	Kerkha	Bambusaceae	22	I	Ba,Fp,Lf,Po
10	*Arundo donax* L.	Shomboqqo	Shembeko	Poaceae	22	I	Ba,Fp,Lf,Po
11	*Bersama abyssinica* Fres.	Ṯeberaco	Azamir	Melianthaceae	65	I	Fi,Md,Sh
12	*Brucea antidysentrica* J.F. Miller	Hatawicho	Gim Qitel	Simaroubaceae	39	I	Fi,Md,Sh
13	*Buddleja polystacha* Fresen.	Bulancho	Anfar	Loganiaceae	1	I	Fd,Fi,Lf,Po
14	*Caesalpina decapetala* (Roth) Alston	Arengema		Caesalpinioideae	30	E	Bf,Fd,Lf
15	*Callistemon citrinus*(Curtis) Stapf.			Myrtaceae	1	E	Bf,Fi,Or
16	*Calpurina aurea* (Lam.) benth.	Çêkkatta	Digitta	Papilionaceae	41	I	Bf,Fd,Fi,Lf,Po,Sf
17	*Carrisa edulis* (Forssk.) Vahl		Agam	Apocynaceae	1	I	Fi,Fo,Lf,Md
18	*Casuarina equisetifolia* L.	Shewshewe	Shewshewe	Casuarinaceae	5	E	Fi,Po,Ti
19	*Ceiba pentandra* (L.) Gaerten.	Yetit zaf	Yetit zaf	Bombaceae	1	E	Fb,Fd,Sh
20	*Celtis africana* Burm. F.	Shîsho	Kewt	Ulmaceae	14	I	Fd,Fi,Ft,Sh
21	*Clausena anisata* (Willd.) Hook. F.ex Benth	Bentelissa	Limich	Rutaceae	1	I	Fd,Md
22	*Combretum molle* R. Br. Ex G. Don	Ṯetele		Combretaceae	3	I	Bf,Fi,Ft,Md,Po,Sf,Sh
23	*Cordia africana* Lam.	Wâdicho	Wanza	Boraginaceae	98	I	Bf,Fi,Fo,Hu,Md,Po,Sf,Sh,Ti
24	*Croton macrostachys* Hochst. Ex Del.	Masincho	Bisana	Euphorbiaceae	65	I	Bf,Fi,Ft,Md,Po,Sf,Sh

Nr.	Botanical name	Vernacular names		Family	Frequency (%)	Origin	Local uses
		Sidamigna	*Amharic*				
25	*Cupressus lusitanica* Mill.	Hômme	Yef. Tid	Cupressaceae	77	E	Fi,Lf,Po,Sh,Ti,
26	*Cussonia ostinii* Chinov.	Anderacco		Arliaceae	1	I	Fd,Md
27	*Diospyros abyssinica* (Hiern.) White	Lokko		Ebenaceae	3	I	Fi,Ft,Po,Sh
28	*Diphasia dainellii* Pichi-Sem.	Lelcho		Rutaceae	17	I	Fi,Fo,Po,Ti
29	*Discopodium penninervum* Hochst.		Ameraro	Solanaceae	1	I	Fi,Ft,Lf,Sf
30	*Dodonaea angusitifolia* L.f.	Etancha		Sapindaceae	13	I	Bf,Fi,Ft,Lf,Md,Po,Sc
31	*Dombeya torrida* (J.F. Gmel.)Bamps			Sterculiaceae	2	I	Bf,Fi,Ft,Po,Sf,Sh
32	*Dovyalis abyssinica* (A.Rich) Warb.		Koshim	Flacourtiaceae	8	I	Bf,Fo,Lf
33	*Dracaena steudneri* Engl.	Lanticho	Etse-patos	Agavaceae	22	I	Fd,Sh,
34	*Ehretia cymosa* Thonn.	Gidincho	Game	Boraginaceae	50	I	Fd,Fi,Ft,Po,Sf
35	*Ekbergia capensis* Sparrman	Oloncho	Lol/Sembo	Meliaceae	40	I	Bf,Fd,Fi,Ft,Md,Po,Sc,Sh,T
36	*Embelia shimperi* Vatke	Qanqo	Enqoqo	Myrsinaceae	3	I	Fi,Fo,Md
37	*Entada abyssinica* Steud. Ex A. Rich.	Tank'adicho	kontir	Mimosaceae	31	I	Fi,Lf,Md
38	*Eriobotrya japonica* Lindl.	Mushmula	Weshmela	Rosaceae	6	E	Bf,Fi,Fo,Po,Sh
39	*Erythrina abyssinica* Lam. Ex. Dc.	Welako	Korch	Papilionaceae	5	I	Bf,Fi,Hu,Lf,Md,Sc,Sf,
40	*Erythrina brucei* schweinf.	Welakko	Korch	Papilionaceae	40	I	Bf,Fi,Hu,Lf,Md,Sc,Sf,
41	*Eucalyptus camaldulensis* Dehn.,	Bahirzafe	K.Bahirzaf	Myrtaceae	95	E	Bf,Fi,Po
42	*Eucalyptus citrodora* Hook.	Bahirzafe	K.Bahirzaf	Myrtaceae	1	E	Bf,Fi,Po
43	*Eucalyptus globulus* Labill.,	Bahirzafe	N.Bahirzaf	Myrtaceae	8	E	Bf,Fi,Md,Po
44	*Eucalyptus saligna* Sm.,	Bahirzafe	K. Bahirzaf	Myrtaceae	3	E	Bf,Fi,Po
45	*Euclea shimperi* (A.DC.) Dandy.	Qanqo	Dedaho	Ebenaceae	4	I	Fi,Fo,Ft,Lf
46	*Euphorbia candelabrum* Trem. & Kotschy.,	Çarricho	Kulkual	Euphorbiaceae	88	I	Fi,Fp,Lf
47	*Euphorbia tirucalli* L.	Anano	Kinchib	Euphorbiaceae	11	I	Lf,Md
48	*Fagaropsis angolensis* (Engl.) Del.	Goddîcho	Sisa (Or)	Rutaceae	32	I	Fi,Fp
49	*Faurea rochetiana* (A. Rich.) Chinov. ex Pichi-serm.,	Dewaqa		Protaceae	10	I	Bf,Fd,Fi,Po

Nr.	Botanical name	Vernacular names		Family	Frequency	Origin	Local uses
		Sidamigna	*Amharic*		(%)		
50	*Ficus elastica*		Yegoma zaf	Moraceae	1	E	Or,Sh
51	*Ficus spp*	Boya		Moraceae	1	I	Fd,Fo,Sc,Sf,Sh
52	*Ficus sur* Forssk.	Odakko	Shola	Moraceae	57	I	Fo,Hu,Sf,Sh
53	*Ficus thonningii* Bl.,	Dinbicho	Dembi (Or)	Moraceae	6	I	Fo,Md
54	*Ficus vasta* Forssk.	Qilto	Warka	Moraceae	19	I	Fi,Sf,Sh
55	*Flacourtia indica (*Burm.f.) Merr.	Hagella		Flaucourtiaceae	3	I	Fi,Fd,Fo,Ft,Md
56	*Gardenia lutea* Fres.	Gambela		Rubiaceae	3	I	Fd,Lf
57	*Grevillea robusta* A. Cunn. Ex. R. Br.		Temenja zaf	Proteaceae	4	E	Bf,Fi,Po,Sc,Sh,Ti
58	*Hagenia abyssinica (*Bruce) J.F. Gmel.	Dadako	kosso zaf	Rosaceae	2	I	Fi,Md,Po,Sc,Sf,Ti
59	*Ilex mitis* (L.) Radlk.	Miqqe	Misir Genfo	Aquifoliaceae	11	I	Fi,Ft,Md,Po,
60	*Jacaranda mimosifolia* D. Don.	Jacaranda	Jacaranda	Bignoniaceae	3	E	Bf,Fi,,Ft,Po,Or,Sh
61	*Jasminium floribundum*Fres.	Dikicha		Oleaceae	5	I	Fi,Md
62	*Jasminium sp.*	Binjle		Oleaceae	7	I	Fi,Md
63	*Juniperus procera* Hochst. Ex Endl.	Hôncho	Tid	Cupressaceae	19	I	Fi,Md,Po,Sh,Ti
64	*Lepidotrichilia volkensii* (Gurke) Leroy	Tontoloma		Meliaceae	1	I	Fi,Ft,Po,Sh
65	*Luenaena leucocephala* (Lam.) De Wit.	Lucina	Lucina	Mimosoideae	3	E	Bf,Fd,Fi,Po,Sc,Sf
66	*Macaranga kilimandsharica* Pax.	Felecco		Euphorbiaceae	10	I	Fd,Fi,Po,Sf,
67	*Maesa lanceolata* Forssk.	Gowacho	Kelewa	Myrsinaceae	30	I	Fi,Lf,Md
68	*Maytenus arbutifolia* (A. Rich.) Wilczeck	Çuçço	Atat	Celastraceae	10	I	Fi,Ft,Lf
69	*Melia azedarach* L.			Meliaceae	6	E	Bf,Fi,Or,Po,Sh
70	*Milletia ferruginea* (Hochst.) Baker	Hengedicho	Birbira	Papilionoideae	88	I	Fi,Ft,Hu,Po,Sf,Sh
71	*Mimusops kummel* Bruce ex DC.,	Bururi/Olati		Sapotaceae	6	I	Fi,Fo,Ft,Po
72	*Moringa stenopetala (*Bak.) Cuf.	Shifera	Shiferaw	Moringaceae	1	E	Bf,Fd,Fo,Md,Sc,Sh
73	*Ocotea kenyensis* Kosterm.	Shoecho		Lauraceae	41	I	Fi,Md,Po,Ti
74	*Olea capensis* ssp. *hochstetteri* (Bak.) Fris & P.S. Green	Setamo	D. Woyra	Oleaceae	31	I	Fi,Ft,Md,Po,Ti

Nr.	Botanical name	Vernacular names		Family	Frequency	Origin	Local uses
		Sidamigna	*Amharic*		(%)		
75	*Olea europaea* L. ssp. *africana(*Mill.) P.S. Green	Ejersu	Woyra	Oleaceae	22	I	Bf,Fi,Md,Po,Ti
76	*Olinia rochetiana* A. Jussieu	Nolle		Oliniaceae	2	I	Fi,Ft,Po
77	*Phoenix reclinata* Jack.	Sâticho	Zenbaba	Arecaceae	14	I	Ba,Fb,Fo,Or,Sc
78	*Phytolaca deodecandra* L' Her.		Endod	Phytolacaceae	1	I	Md,Sc
79	*Pittosporum abyssinicum* Del.	Boncho		Pittosporaceae	8	I	Fi,Ft,Po
80	*Pittosporum virdiflorum*Sims., ssp. *Quantinianum* Cuf.	Erba		Pittosporaceae	1	I	Fi,Ft,Po
81	*Podocarpus falcatus*(Thunb.) Mirb.	Dagucho	Zigba	Podocarpaceae	70	I	Fi,Md,Po,Sh,Ti
82	*Polyscias fulva* (Hiern.) Harms	Kobre	Yez.Wonb.	Araliaceae	31	I	Fi,Sf,Sh
83	*Prunus africana* (Hook.f.) Kalkm.	Garbicho	Tikur Enchet	Rosaceae	34	I	Bf,Fi,Hu,Md,Po,Sh,Ti
84	*Rapanea simensis* (Hochst.ex DC.) Mez.	Morocho		Myrsinaceae	3	I	Bf,Fi,Po
85	*Ricinus communis* L.	Qenbo'o	Gulo	Euphorbiaceae	43	I	Fd,Fo,Md,Sc
86	*Ritchiea albersii* Gilg.	Koqqo	Dingay Seber	Capparidaceae	4	I	Fd,Fi,Md
87	*Rosa abyssinica* Lindl.		Qega	Rosaceae	2	I	Fo,Lf,Md
88	*Rubus apetalus* Poir., .	Gora	Enjori	Rosaceae	1	I	Fi,Fo,Lf
89	*Sapium ellipticum* (Hochst.) Pax	Gâncho	Arboche	Euphorbiaceae	17	I	Fi,Ft,Sh
90	*Schfflera abyssinica* (Hochst. Ex A. Rich.) Harms	Gatâmo	Geteme	Araliaceae	9	I	Bf,Fi,Ft,Hu,Lf,Ti
91	*Schinus molle* L.		Berbere Zaf	Anacardiaceae	4	E	Bf,Fi,Or,Sc,Sh
92	*Sesbania sesban* (L.) Merr.	Sesbania	Sesbania	Papilionoideae	17	I	Fd,Fi,Sc,Sf,Sh
93	*Spathodea campanulata* Beauv.			Bignoniaceae	3	E	Fi,Hu,Or,Sh
94	*Strychnos mitis* S. moore	Mulqa		Loganiaceae	1	I	Fi,Ft,Lf,Md,Po
95	*Syzigeem guineense* (Wild.) DC. var. *macrocarpum* Engl.	Woraricho		Myrtaceae	19	I	Bf,Fi,Fo,Ft,Md,Po,Ti
96	*Syzigeem guineense* (Willd.) DC.,	Dûwancho	Dokma	Myrtaceae	48	I	Bf,Fi,Fo,Ft,Md,Po,Ti
97	*Teclea nobilis* Del.	Ha'dêssa		Rutaceae	12	I	Fi,Ft,Md,Po
98	*Trichocladus ellipticus* Eckl. & Zeyh.	Manissa		Hamamelidaceae	1	I	Fi,Ft,Po
99	*Vernonia amygdalina* Del.	Hecho	Grawa	Asteraceae	58	I	Fd,Fi,Lf,Md,Sc,Sf

Nr.	Botanical name	Vernacular names		Family	Frequency	Origin	Local uses
		Sidamigna	*Amharic*		(%)		
100	*Vernonia auriculifera* Hiern	Rêjjicho	Gujjo	Asteraceae	43	I	Fd,Lf,Sc
101		Abeba Zaf	Abeba Zaf		37	E	Fi,Lf,Or,Po
102		Batarrqicco			13	I	Fd,Fi,Po,Sh
103		Bolkosso			11	I	Fi,Ft,Po,Sh
104		Danikuke			7	I	Fi,Lf,Po
105		Ga'da			4	I	Fd,Fi,Po
106		Galicha			4	I	Fi,Ft,Po
107		Gelgelcco			4	I	Fi,Po,Sh,Ti
108		Giratoischo			3	I	Fd,Fi,Lf,Sc
109		Kokole			3	I	Fd,Lf,Sc
110		Lege			3	I	Fi,Po,Sh
111		Malasincho			2	I	Fi,Ft,Po,Sh
112		Miraba			2	I	Fi,Po,Sc,Sh
113		Qiṯimalcco			2	I	Fi,Lf,Sc
114		Shigasho			1	I	Lf,Sc
115		Shilcho			1	I	Fd,Lf
116		Shomalcho			1	I	Fi,Po,Sh,
117		Sololsa			1	I	Fi,Po,Ft
118		Sonisofa			1	I	Fi,Po,Sh,
119		T̲ama'e			1	I	Fi,Lf,Sc
120		Udo			1	I	Fi,Sc

Legend

Frequency = Percentage of farms where the tree species is found *Origin:* I = Indigenous; E = Exotic

Ba = Basketry; Bf = Bee forage; Fb = Fiber; Fd = Fodder; Fi = Firewood; Fo = Food; Fp = Floor panel; Ft = Farm toold and tool handles; Hu = Household utensils; Lf = Live fences; Md = Medicine; Po = Poles and posts for local construction; Sc = Soil conservation; Sf = Soil fertility m,aintenance; Sh= Shade; Ti = Timber

CHAPTER 6

6. Trees and stock of wood in the homegarden agroforestry systems of Southern Ethiopia

6.1 Introduction

Trees are integral components of most agricultural systems in the tropics playing vital roles in the livelihood of rural and urban populations. They provide fuelwood, the major energy source in these areas, wood for construction and other purposes, and their timber provides cash to many rural families. Moreover, trees protect agricultural lands and maintain or enhance their productivity (Fernandes and Nair, 1986; Long and Nair, 1999). With the rapid increase in population, off-farm tree resources in most developing countries are becoming scarce and thus farmers manage trees on their farms (Arnold and Dewees, 1995). Tropical homegardens are agroecosystems where intensive tree management is practiced in integration with a multitude of crops. Despite the presence of a range of literature on tropical homegarden agroforestry systems, information on standing stock of wood is rare (but see Kumar *et* al., 1994).

Homegardens are the dominant agricultural systems in the densely populated highlands of southern Ethiopia. They cover extensive areas and are characterized by two dominant crops, coffee (*Coffea arabica* L.) and enset (*Enset ventricosum* (Welw.) Cheesman). The latter is a perennial herbaceous monocot and a staple food for an estimated 10 million people in Southern Ethiopia. The two dominant crops are grown in an intimate association with different types of cereals, vegetables, fruits, pulses and root and tuber crops in multistorey configurations with different types of trees and shrubs. The diversity as well as density of tree species in these homegardens is generally very high. The average number of tree species in a homegarden is 21 and it reaches as high as 55 in large farms (Chapter 5).

Intensive management of trees in these homegardens contributes to the welfare of the farm households, and plays a role in the regional economy. Almost all the wood used for fuel, construction, furniture, etc., in the region comes from these farms but there is no information on the volume harvested each year or on the volume of the standing stock. Because of lack of any such data, on-farm wood production is often underestimated in the national forestry statistics of Ethiopia (EFAP, 1994). The volume of wood in farms varies due to physical and socio-economic factors. For instance, farmers with small land holding cannot have a large stock of trees since the available land is primarily used to produce crops for consumption. Large holders, on the other hand, could produce a large volume of wood (Scherr, 1995). Also a good access to markets could encourage farmers to engage in intensive management of trees for marketing (Gilmour, 1995).

One of the features of on-farm tree management is that the biological characteristic of a tree is often taken into account to determine where it should be grown. For instance, trees that contribute positively to agricultural crops are grown dispersed in crop fields, while trees that compete with crops are planted separately. In general, farmers select tree species suitable to each tree growing location and vary the density of planting. Arnold and Dewees (1995) have identified five different patterns of planted trees on farms. These are trees grown a) on non-arable fallow land, b) around the house c) along boundaries d) intercropped on arable land and e) monocropped on farmland (farm woodlots). Among these, the first category of planted trees is not relevant to homegardens such as the present study area because fallow lands do not occur. The remaining patterns are common, but the stocking rate and woody biomass distribution in the different locations is not known. These homegardens have two basic components, enset and coffee, but four different prototypes of these systems can be recognized (Chapter 3). It is not also clear whether standing stock varies with the prototypes.

This chapter assesses the standing stock of wood in the homegardens of Sidama, Southern Ethiopia and identifies the distribution of wood biomass across the different tree growing locations in the farms. Specific objectives of this chapter are a) to determine the volume of standing stock of wood in the homegardens, b) to determine the distribution of density and wood volume of trees across the different patterns of tree growing, c) to compare wood stock of the different prototypes of the system, and d) to identify physical and socioeconomic variables that influence the stock of wood and its distribution.

6.2 The study areas

Homegardens involving enset and coffee are widely practiced in the highlands of Southern Ethiopia. The research was conducted in Sidama, one of the administrative zones of the Southern Ethiopian Regional government.

The study was carried out in 12 sites or Peasant Associations selected from four Woredas where these agroforestry systems are practiced (Figure 2.1). In selecting the sites, stratified sampling procedures were followed in order to represent possible local variations. First, four representative woredas were selected. Then, 2-4 Peasant Associations (PAs) were selected from each woreda on the basis of their access to markets and major roads, because these variables were believed to affect tree management practices. The research sites were located within 14 to 80 kilometers from Awassa, the regional capital. From each PA, 12 households were selected on the basis of their land holding. At each PA farmers are categorized as poor, medium and rich by the local administration based on the major criterion of land holding, but also additional criteria such as livestock holding and area of coffee production. From each category of farmers, four households were selected at random, making a total of 12 households per PA and 144 households for the whole study.

6.3 Methods

Data were collected from 144 sample households. The households often have one piece of land with a house (houses) and the gardens surrounding it, but few of them have additional garden within short a distance in the same PA. Data were collected from all gardens (farm fields) of each household. It should, therefore, be noted that the homegardens presented in this chapter are equivalent to a 'farm' system.

Four different types of tree growing locations could be distinguished in these homegardens. These are a) trees dispersed in residential and grazing areas, b) trees dispersed inside crop fields c) trees grown on boundaries and d) trees grown in blocks (as woodlots). Area of the farm and that of the different locations was measured. Then, all trees and shrubs with a minimum diameter (diameter at breast height- dbh) of 5 centimeters were counted and measured for each of the four location types. Diameter was measured using calipers and diameter tapes, while hyposometers were used to measure height of the trees.

Approximation of bole volume of the trees was made using the formula from Spurr (1952) by which volume is represented as, $Vp = \pi r^2 h\ (0.5)$, where, r = bole radius at breast height and h = tree height. Then total volume of standing stock at farm level and for the respective location types was calculated. Volume of wood per hectare was calculated by dividing total standing volume with area of the respective farm or location type.

The total volume of wood of homegardens as well as the wood from different tree growing locations was calculated and then compared among homegardens of the different sites (PAs) and Woredas using Analysis of Variance and Post-hoc tests. The standing stock of wood was also compared among the different prototypes of the enset-coffee systems. The effects of biophysical and socioeconomic variables on wood volumes of homegardens were determined using multiple linear regression. A separate multiple regression model was used for wood volume of farms and volume per hectare, where each model included one of these dependent variables and a set of independent variables, which included access to markets and highway, altitude, slope of farm, farm size, area of woodlot, farm labor force and involvement in off-farm activities.

In this chapter, trees that are primarily grown for their non-wood products such as fruit trees are not considered. The list of tree species grown in these homegardens is presented in Appendix 5.1.

6.4 Results

Standing stock of trees

The average standing volume of wood in the homegardens of Sidama is 50.4 m^3 per farm (24 m^3 ha^{-1}) with huge variations across woredas, PAs and households. Standing stock of trees varied significantly among the Woredas (F-test, $P<0.05$) and homegardens in Aleta Wondo had the highest mean standing volume of 90.9 m^3 of wood (Figure 6.1). This volume is 2 to 3 times higher than the other woredas, indicating that Aleta Wondo farms are rich in wood resources. This is, however, for a large part due to the larger farms in Aleta Wondo.

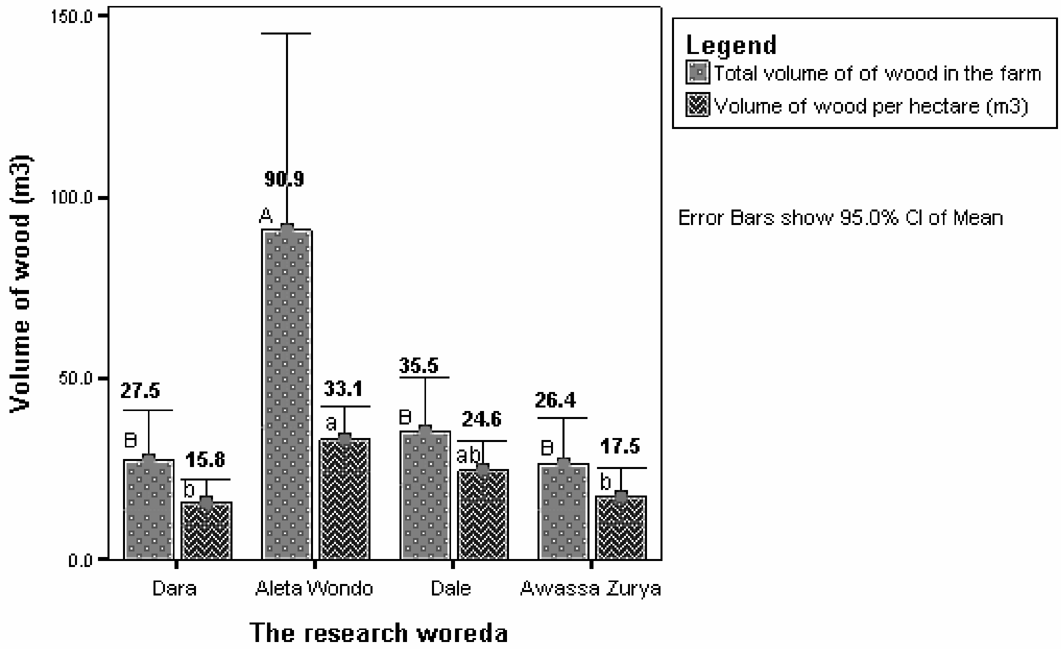

Figure 6.1 Mean standing wood volume of homegardens per farm and per hectare in the study woredas. Note: Capital letters on the top of the bars indicate DMRT values on wood volume of homegardens among the Woredas while lower case letters compare wood volume per hectare.

Also the sites (PAs) had a significant effect on the standing stock of trees both at farm level (F-test, $P<0.05$) and on a hectare basis (F-test, $P<0.001$) (Table 6.1). Belesto PA, which is located in Aleta Wondo Woreda, had the maximum average volume of 159.5 m^3 of wood per farm (51.2m^3 ha^{-1}). The maximum volume of 1120 m^3 of wood per farm was found in a 7.46 ha large homegarden in Sheyicha PA. About 40% of this area is allotted to a woodlot in which large native trees and eucalyptus are dominant. Outside the woodlot, mature and giant indigenous tree species such as *Cordia africana, Syzigium guineense, Ficus sur* and *Milletia ferruginea* are found widely scattered inside the farm and grazing areas. On the other hand, Qomato PA, which is located at a lower altitude and close to a highway, had the lowest average volume of 10.1 m^3 per farm. The lowest volume of 0.1 m^3 of wood was recorded at a small farm in the Tesso Peasant Association.

Table 6.1 Mean volume of standing trees in the homegardens of the research PAs (m^3).

Site (PA) (n/PA = 12)	Woreda	Altitude (meters)	Volume per farm Mean	SD	Volume per hectare Mean	SD
Setamo	Dara	1840-2040	38.8 [c]	43.5	20.0 [bc]	12.8
Shoyicho	"	1840-1920	33.6 [c]	54.2	21.4 [bc]	28.2
Qomato	"	1610-1700	10.1 [c]	7.6	6.0 [c]	4.0
Belesto	Aleta Wondo	1910-2000	159.5 [a]	229.9	51.2 [a]	46.2
Lela Honcho	"	1740-1820	42.2 [c]	41.2	27.7 [bc]	19.2
Tesso	"	1520-1730	24.7 [c]	25.8	12.9 [c]	9.3
Sheyicha		1910-1970	137.1 [ab]	283.9	40.3 [ab]	33.6
Ferro 1	Dale	1780-1890	65.5 [bc]	60.7	27.3 [bc]	20.9
Ferro 2	"	1860-1940	19.3 [c]	18.0	26.4 [bc]	24.9
Tula Aposto	"	1710-1740	21.7 [c]	25.7	20.0 [bc]	27.6
Chefasine	Awassa Zurya	1820-1870	31.6 [c]	30.4	26.8 [bc]	20.7
Abela Tula	"	1830-1940	21.3 [c]	29.5	8.2 [c]	8.2
Total (n=144)			50.4	116.0	24.0	26.5
F-test (P)			<0.05		<0.001	

Note: Means followed by different letters are significantly different at P<0.05, according to Duncan's Multiple Range Test (DMRT)

Wood in the different farm locations

Density of trees and standing stock of wood varied according to tree growing location types. Inside grazing lands and crop fields, trees are scattered sparsely to serve as shade, while in boundaries and woodlots they are densely stocked. At a regional level, out of the total average volume of 50.4 m^3 of wood per farm, 15.8 m^3 (31%) is found scattered inside crop fields and grazing lands while the remaining 69% is found in the boundaries and woodlots (Figure 6.2a). In terms of number of trees, 94 out of the total average of 855 trees are found scattered inside farms and grazing areas (Figure 6.2b). The scattered trees constitute 11% of the total number, but contribute to 31% of the total volume of wood. The trees on boundaries and woodlots, which account for 89% of the total number, contribute to 69% of the volume. Thus, individual trees in boundaries and woodlots are relatively small in size.

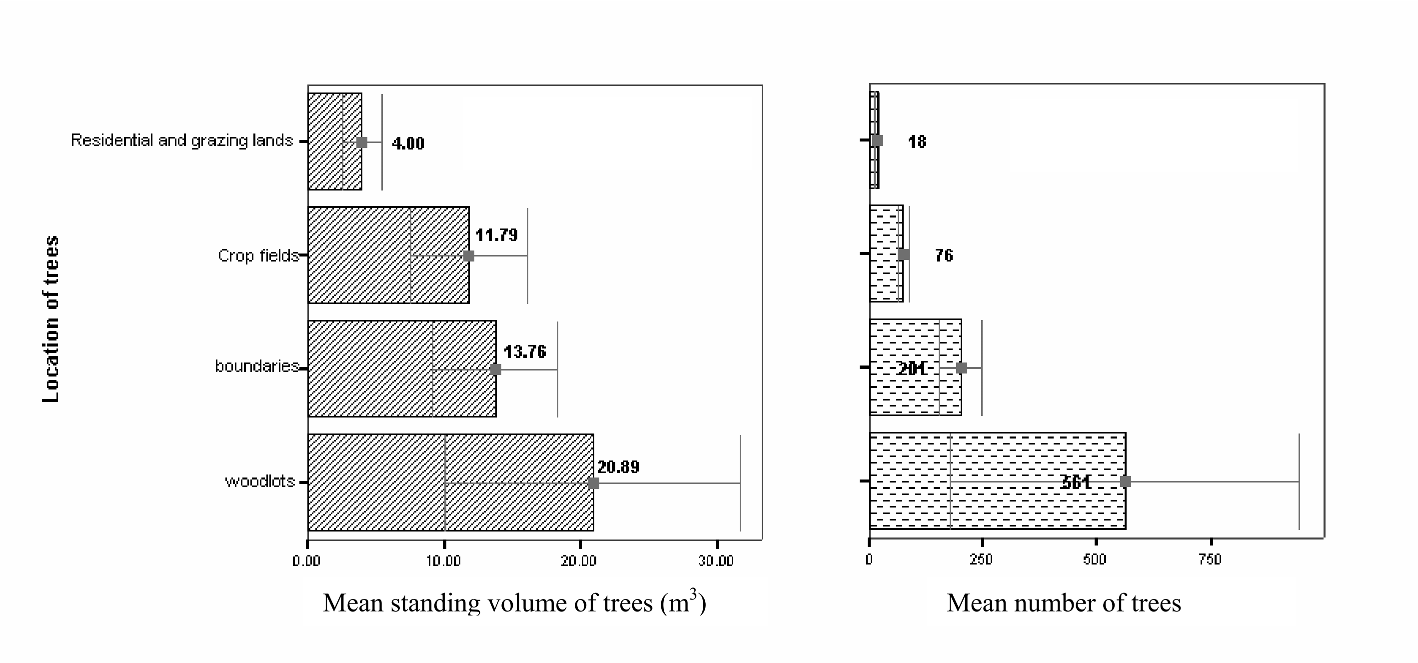

Figure 6.2 Mean standing volume (a), and mean number (b) of trees in the different tree growing locations of the homegardens. Error Bars show 95.0% CI of Mean.

Woodlots have an average density of 5100 trees ha^{-1} and a standing stock of 181.0 m^3 ha^{-1}, while boundaries have a stock of 172.0 m^3 ha^{-1} (Table 6.2). In the crop fields, trees are scattered widely and they have the lowest average volume of 10.3 m^3 ha^{-1}. The volume per hectare of trees grown on boundaries and woodlots is very high, but the area they occupy is only 13% of the farms. On the other hand, crop fields and grazing areas have a low stock of trees but they cover 87% of the total farm area. Hence, when the study sites are considered as a whole, the proportion of wood from the woodlots is high. However, when the volume share of each location type is calculated for each farm, the highest average standing stock (34.8%) was recorded for trees grown scattered inside the crop fields, with values ranging from a mean of 23.6% at Belesto PA to 52.1% at Tesso PA (Table 6.3). Trees grown on boundaries had an average volume share of 32% with PA averages of 13.6 to 46.6%. Trees grown in woodlots had an average volume share of 22.7% with values ranging from 12.3 to 38.7%, but the variation across the farms located in different PAs was not significant. The lowest average proportion of wood volume (10.5%, range 4.5 - 24.9%) comes from trees scattered in home and grazing lands and the variation across the farms located in the different PAs was significant.

Table 6.2 Mean area, number and volume of trees in the different tree growing location types.

Tree growing location types	*Mean area (ha)*	*Nr. of trees ha^{-1}*	*Volume of trees (m^3 ha^{-1})*
Residential and grazing lands (n=144)	0.22	84	18.2
Crop fields (n=144)	1.15	66	10.3
Boundaries (n=134)	0.07	2794	172.0
Woodlots (n=69)	0.14	5100	181.0

Note: The area of boundary trees was calculated by adding one meter on either side of the row/rows of trees

Table 6.3 Mean volume of trees in the different tree growing locations as a percentage of total wood volume in each farm (%), across the sites.

Site (PA) (n/PA = 12)	**Residential and grazing lands**		**Crop fields**		**Boundaries**		**Woodlots**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Setamo	7.9 ^{bc}	15.3	41.2 ^{abc}	20.4	38.6 ^{abc}	28.7	12.3 ^{b}	23.4
Shoyicho	8.7 ^{bc}	8.4	38.4 ^{abc}	26.1	25.3 ^{bcd}	23.1	27.6 ^{ab}	38.6
Qomato	4.5 ^{c}	5.9	48.8 ^{ab}	20.8	30.8 ^{abcd}	20.9	15.8 ^{ab}	28.9
Belesto	9.1 ^{bc}	6.8	23.6 ^{c}	17.7	28.7 ^{abcd}	24.1	38.6 ^{ab}	36.7
Lela Honcho	10.0 ^{bc}	6.9	28.7 ^{c}	10.5	45.1 ^{ab}	18.9	16.1 ^{ab}	22.6
Tesso	7.3 ^{bc}	7.6	52.1 ^{a}	30.4	20.2 ^{cd}	22.4	20.4 ^{ab}	31.7
Sheyicha	5.9 ^{c}	6.0	28.9 ^{c}	15.7	46.6 ^{a}	21.1	18.6 ^{ab}	22.2
Ferro 1	11.0 ^{bc}	12.5	38.5 ^{abc}	19.3	30.2 ^{abcd}	13.4	20.3 ^{ab}	23.4
Ferro 2	10.2 ^{bc}	10.5	31.9 ^{bc}	18.0	41.6 ^{ab}	23.3	16.4 ^{ab}	28.0
Tula Aposto	24.9 ^{a}	24.3	27.4 ^{c}	20.1	26.3 ^{abcd}	24.0	21.4 ^{ab}	33.0
Chefasine	18.5 ^{ab}	21.3	24.7 ^{c}	17.1	13.6 ^{d}	14.4	43.2 ^{a}	31.5
Abele Tula	8.2 ^{bc}	7.9	33.3 ^{bc}	23.0	37.6 ^{abc}	27.6	21.0 ^{ab}	34.0
Mean	*10.5*	*13.3*	*34.8*	*21.6*	*32.0*	*23.5*	*22.7*	*30.2*
F-test (P)	<0.01		<0.01		<0.01		ns	

Note: Means followed by different letters are statistically different at P<0.5, according to DMRT.

Do the prototypes differ in available wood?

The original type, enset-coffee-maize sub system had the highest stock of wood per farm (70.9 m^3) as well as per hectare (30.6 m^3) (Figure 6.3). The enset-coffee-maize-chat and pineapple systems had the lowest average wood volume (9.4 m^3 ha^{-1}). The proportion of wood from the different tree growing location types was also compared among these prototypes (Table 6.4). In the enset-coffee-maize systems, about 70% of the wood volume is constituted by trees grown inside crop fields and on boundaries. However, in the subsistence crop dominated enset-coffee-maize-sweet potato systems and cash crop oriented enset-coffee-maize-chat systems the contribution of these two locations was about 54%. Here, trees in the residential and grazing lands and woodlots, have slightly higher volume share, respectively.

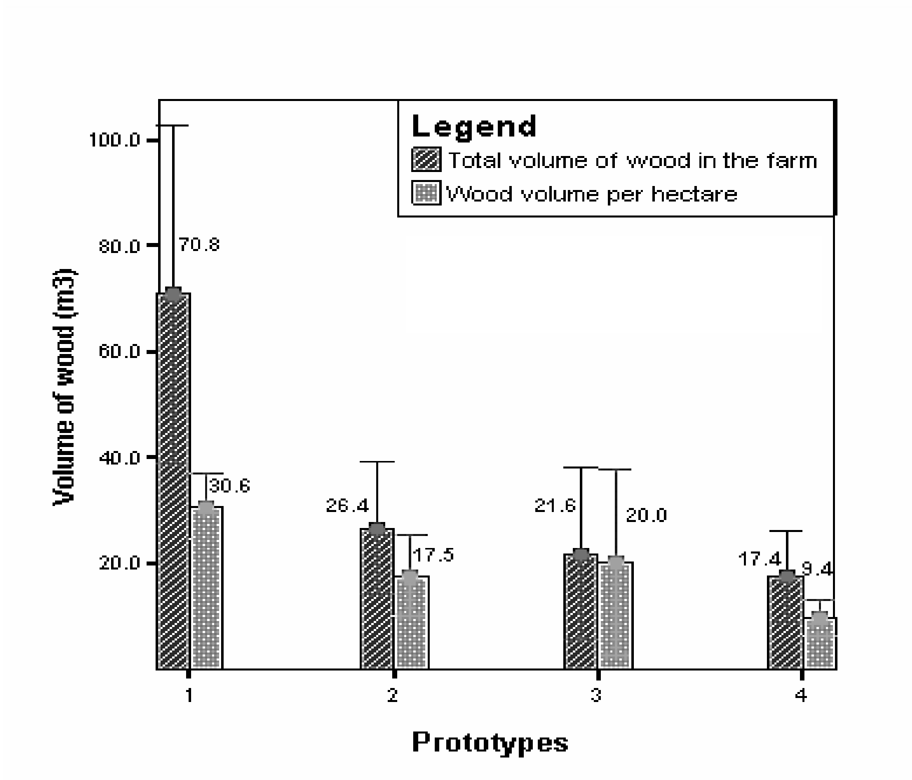

Figure 6.3 Mean volume of wood at the different prototypes of the enset-coffee systems. Error Bars show 95.0% CI of Mean.

Key:

1 = Enset - coffee - maize systems (n=84)
2 = Enset - coffee - maize - chat systems (n=24)
3 = Enset - coffee - maize - sweet potato systems (n=12)
4 = Enset - coffee - maize - chat - pineapple systems (n=24)

Table 6.4 Mean proportional wood volume share of the tree growing location types across the different prototypes of the enset-coffee systems (%).

Prototypes of the system	**Mean percentage wood volume in the different locations**			
	Residential and grazing lands	Crop fields	Boundaries	Woodlots
Enset-coffee-maize (n=84)	9.0 [b]	33.0 [b]	36.6 [a]	21.4 [a]
Enset-coffee-maize-chat (n=24)	13.3 [b]	29.0 [b]	25.6 [a]	32.1 [a]
Enset-coffee-maize-sweet potato (n=12)	24.9 [a]	27.4 [b]	26.3 [a]	21.4 [a]
Enset-coffee-maize-chat-pineapple (n = 24)	5.9 [b]	50.5 [a]	25.5 [a]	18.1 [a]
Mean volume (%) (n=144)	*10.5*	*34.8*	*32.0*	*22.7*

Note: Means followed by different letters are statistically different at P<0.5, according to DMRT.

Volume of common tree species

A total of 120 tree species were recorded in the homegardens of Sidama (Chapter 5), but few species are dominant in terms of number as well as biomass production. The eucalyptus, particularly *E. camaldulensis* is the most abundant species accounting for 41% of the total standing volume of trees in the farms. The other dominant species are the native species, *Cordia africana, Podocarpus falcatus, Milletia ferruginea* and *Ficus spp.,* each contributing from 6.6 to 16.3% of the total wood volume in the farms (Figure 6.4). It is important to note that the above four native species together accounted for 16% of the total number of individual trees, but they contributed to 36% of the total volume, indicating that these trees are relatively large. These species, except *P. falcatus,* are widely dispersed inside crop fields as shade trees, and farmers consider them as complementary to crop production. Often, their branches are lopped to reduce competition for light. *P. falcatus* and *C. africana* also produce good quality timber which is widely marketed in the region.

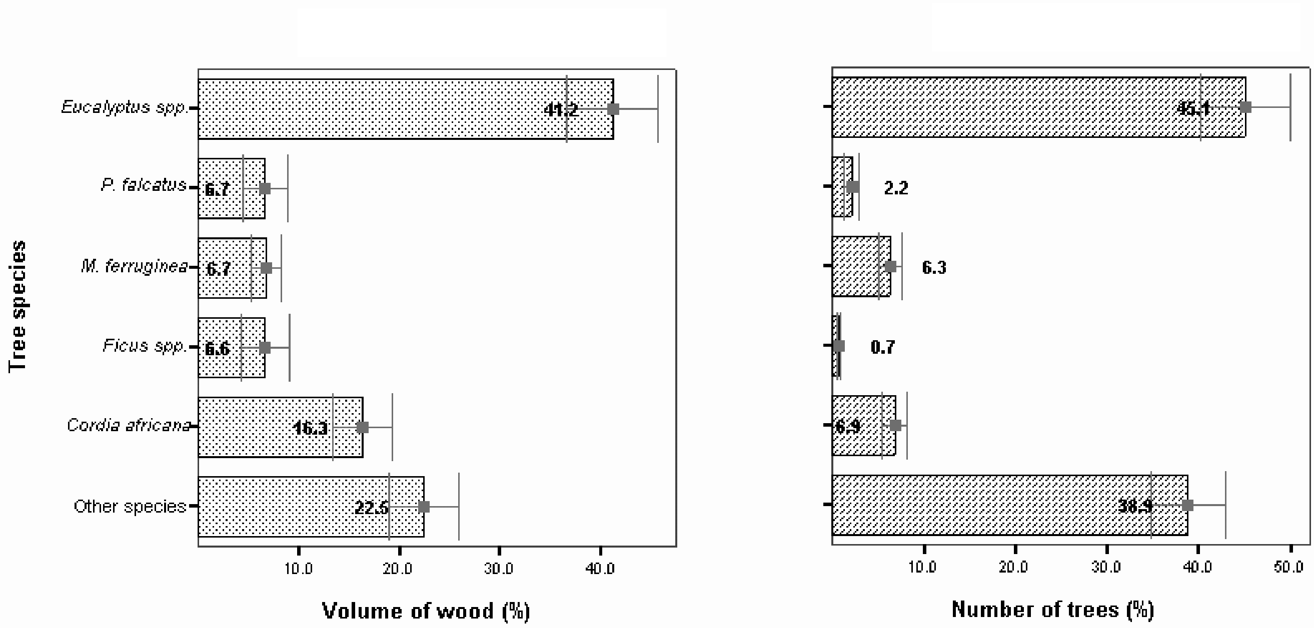

Figure 6.2 Mean standing volume (a), and mean number (b) of the different tree species in the homegardens. Error Bars show 95.0% CI of Mean.

Factors influencing standing stock of trees in homegardens

Farm size, area of woodlots and altitude positively affected total volume of wood per farm as well as the volume per hectare while proximity to major roads had a negative effect. The proximity of markets had only a negative effect on volume (Table 6.5).

Farm size, which is highly correlated with economic well being of farmers (r=0.72), has affected the distribution of wood stock in the tree growing location types. The wood volume of the different location types was compared across the different economic categories of farmers and it was found that the contribution of the locations differ widely (Figure 6.5).

Table 6.5 Regression analysis of standing stock of wood in homegardens with farmer's environments.

Factors	Standing volume of wood (m^3)	
	Total volume	Volume ha^{-1}
Adjusted R^2	**0.67*** **	**0.49*** **
Physical environment		
• Altitude of the farm	0.16**	0.15*
• Slope of the farm	ns	ns
Socioeconomic environment		
• Proximity to markets	ns	-0.13*
• Proximity to highway	-0.26**	-0.34***
• Farm size	0.52***	0.15*
• Area of woodlot	0.44***	0.44***
• Number of farm units	ns	ns
• Number of farm labor force	ns	ns
• Involvement in off-farm activities	ns	ns

Note: ns = not significant; *, **, *** = significant at P(F-test) < 0.05, 0.01 and 0.001, respectively.

Poor farmers who are short of land have most of the wood from trees scattered inside the crop fields, and this proportion decreases progressively with an increase in economic status. On the other hand, the wood from woodlots increases in opposite direction.

A total of 69 households (48%) have woodlots within the farm, in addition to trees grown in the other locations. The size of the woodlots ranged from 100 m^2 to 3 hectares. In relation to total farm size, the area of the woodlots represented from 1 up to 40% of the farm. Farms with woodlots had more standing stock of wood than those without woodlots, and the volume increased with an increasing area of woodlot.

Standing stock of trees per farm and per hectare increased with increasing altitude (F-test, $P<0.01$). Farms located in the low altitude sites of Tesso and Qomato PA had a mean tree volume of 6.0 and 12.9 m3 ha^{-1}, respectively which is far less than the overall average of 24.0 m3 ha^{-1}.

Distance of the sample farms to the highway varied from 20 meters to 26 kilometers, with a mean of 9 kilometers. Proximity to highways had affected negatively the total volume of wood per farm ($P<0.01$) and volume per hectare ($P<0.001$). Proximity to markets has significantly reduced the volume of trees per hectare.

Other factors such as slope of farm, number of farm labor force, involvement in off-farm activities and age and educational status of the household head did not have a significant influence on standing volume of trees.

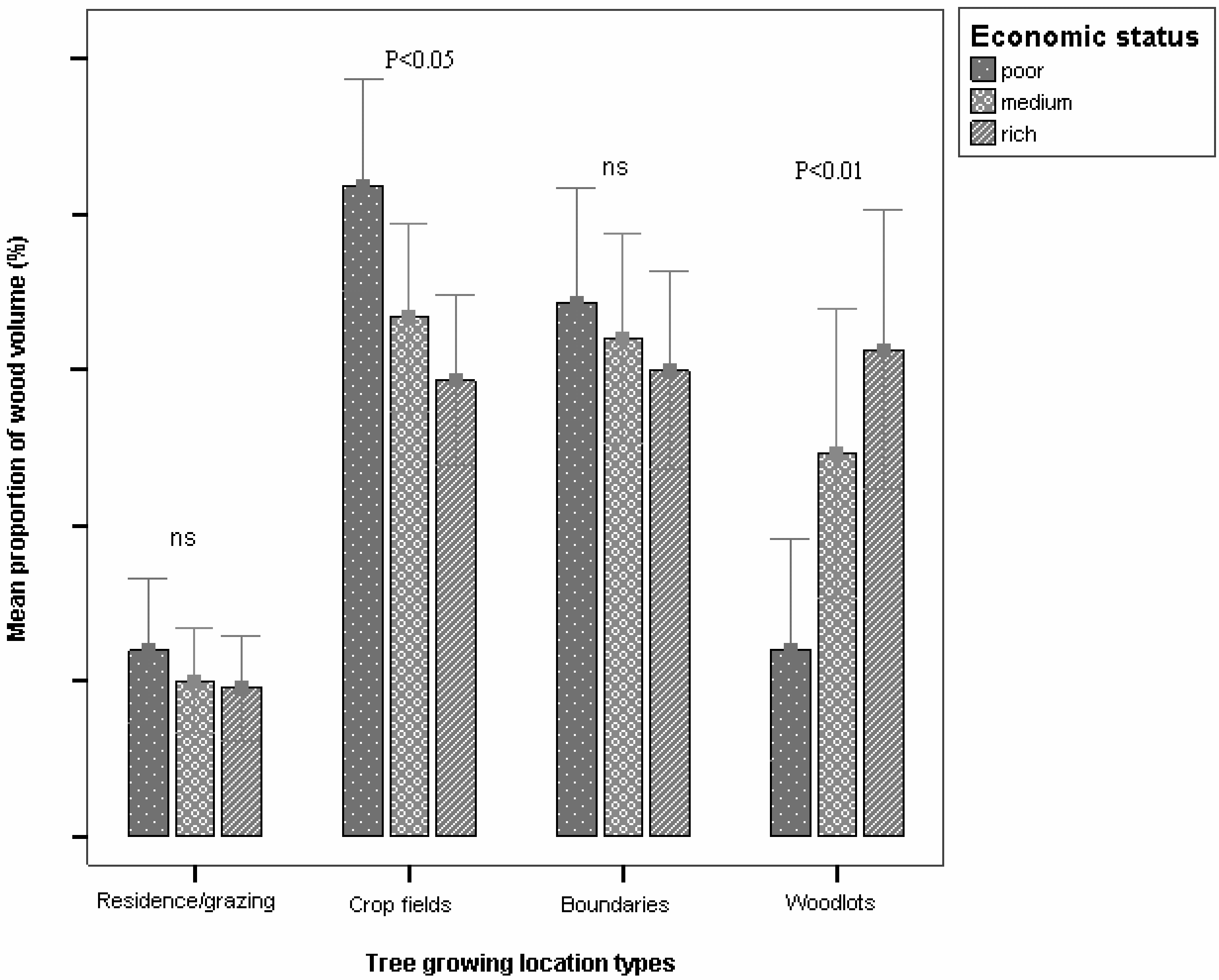

Figure 6.5 Mean % volume of wood in the different location types in relation to economic status of farmers. Error Bars show 95.0% CI of Mean. The values on top of the bars indicate the level of significance within each set of tree growing locations.

6.5 Discussion

Wood for fuel and timber

The average standing volume of wood in the homegardens of Sidama was 50.4 m^3, and the mean volume per hectare was 24 m^3. Wood volume increased with farm size. About 20% of the households (all small holders) have a stock of less than 5 m^3 and 11% have more than 100 m^3. The remaining 69% of the households have 5 to 100 m^3 of wood stock in their farms. In the homegardens of Kerala, Kumar *et* al. (1994) found that the average standing stock of commercial timber and fuelwood was 6.6-50.8 and 23-86 m^3 ha^{-1}, respectively. However, the coconut tree which is primarily grown for its non-wood products, accounted for 63% of the commercial timber and 72% of the fuelwood (Kumar *et* al., 1994). In this study fruit trees that are primarily treated as food crops, are not considered in the calculation of wood volume. However, when fruit trees are very old, farmers harvest them and use the wood for fuel and other purposes. Unproductive and dense branches of these trees are also lopped and the wood used for different purposes. For instance, fruit trees such as avocado (*Persea americana*) and white sapote (*Kasimora edulis*) grow to a large size producing a volume that sometimes exceeds one meter cube of fuelwood per tree. When the volume of wood harvested from fruit trees is taken into account, the actual supply of wood in Sidama homegardens is higher than our conservative estimates.

If we consider the rural Ethiopian average fuelwood consumption to be 1.19 m^3 per capita yr^{-1} (EFAP, 1994), and calculate the fuelwood supply of the households from their farms we may conclude that most households produce at least enough wood for their own consumption. Some 72% of the households can meet their fuelwood requirement for one year and 36% have supply for more than 4 years (Figure 6.6). On the other hand, in interviews conducted in all of these households on fuelwood supply situation, 88% responded that they meet all their fuelwood requirements from their farms, indicating that the actual supply of fuelwood from the farms is higher. Apparently, the farmers use old fruit trees, lopped branches of shade trees, dead branches, undesirable under growth and even crop residues for fuel. Thus, the homegardens seem to satisfy the energy requirements of households.

The contribution of Sidama homegardens to the fuelwood supply of households exceeds the figures mentioned in some earlier reports. In a study conducted in Central Java, Indonesia, Wiersum (1977) reported that 43-81% of fuelwood requirements of the households are met by homegardens. Fernandes *et* al. (1984) also reported that the Chagga homegardens satisfy 1/4 to 1/3 of the fuelwood requirements of households, while the rest is collected from forest reserves. In the present study area, there are no forests or other farm fields from where fuelwood could be collected, nor are there alternative sources of energy. Thus, the farmers are almost entirely dependent on their homegardens for their fuelwood consumption, and for most of other wood products. Obviously, the wood from these gardens is not used only for fuel, but also for different purposes such as construction of houses and fences, production of furniture, farm implements and household utensils.

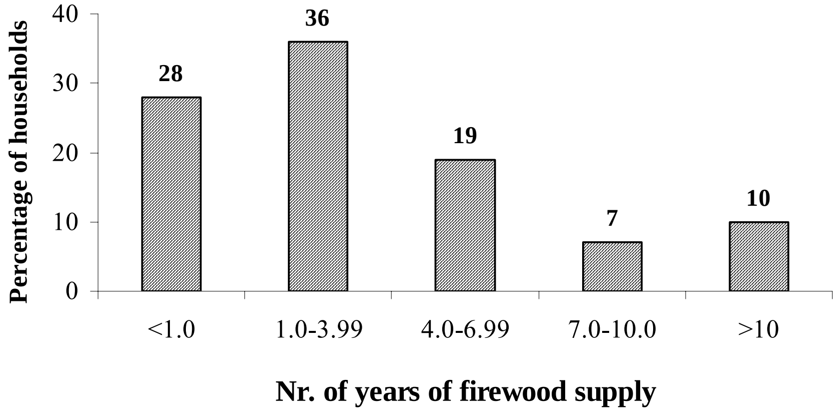

Figure 6.6 Number of years the households can potentially obtain firewood supply from the standing stock of trees in their homegardens (n=144). The calculation is made by dividing the current standing stock wood in each farm with the household's annual firewood consumption by using per capita consumption rate of 1.19m^3 per capita per annum. (Annual growth increments of trees are not considered).

In addition to fulfilling wood requirements of the farming communities, these homegardens supply urban areas in the region with construction poles and posts, sawn timber, fuelwood and other tree products. The large surplus of wood in many gardens illustrates this fact. Likewise, Krishnankutty (1990) has indicated that 74.4 to 83.6% of the total wood requirements of Kerala state, India is supplied from homegardens.

Location of trees

The density and standing stock of trees in the homegardens varied with tree growing location types. In crop fields and grazing areas, tree density and standing stock is generally low but boundaries and woodlots have very high stock. Trees scattered inside the farms are almost entirely native species that are regarded by farmers as complementary to crop production. Farmers indicate that they select scattered trees on the basis of their suitability for shade, litter contribution, soil and water conservation as well as for provision of different products. The average number of trees inside crop fields is 66 trees ha^{-1} and the trees are frequently lopped or pollarded to minimize competition with agricultural crops, and to get firewood. The density obtained here agrees with the report of Tessema Chekun (1997) which indicated that the density of coffee shade trees in Southern Ethiopia was about 60 trees ha^{-1}. Although, the density of scattered trees in crop fields and grazing areas is low, most of the wood comes from these location types because they constitute an average of 87% of the farm areas. On the other hand, farmers attempt to maximize production of woody biomass on woodlots and boundaries by planting fast growing exotic species, mainly eucalyptus, in high densities. These trees are often grown in short rotation cycles of 3 to 8 years with densities as high as 10000 trees ha^{-1}.

The standing volume of wood differed with the different prototypes of the system. The enset-coffee- maize systems have the highest wood volume. In the other prototypes standing stock of wood depended on whether the system is oriented towards cash cropping or subsistence cropping. In the prototypes where cash crops such as chat and pineapple have a large share, the volume of wood is generally low because farmers grow trees mainly for their own consumption.

Common tree species

Among the large number of tree species prevailing in the homegardens of Sidama, five species contributed to 62% of the number of individuals and to 77% of the volume of wood. These species are *E. camaldulensis, C. africana, M. ferruginea, P. falcatus* and *Ficus spp*., and they are preferred due to their specific qualities such as fast growth, timber and quality. For instance, eucalyptus grows fast and its posts and split-wood are highly demanded for housing construction, and the wood is also sold for fuel. Such demands in urban areas have motivated many farmers to grow eucalyptus as a cash crop. This agrees with earlier reports that farmers grow trees primarily to satisfy their wood requirements, but they also respond to commercial opportunities (Warner, 1993; Arnold and Dewees, 1995; Scherr, 1995). *P. falcatus* and *C. africana* are important sources of quality timber, and they constitute the majority of timber traded in the region. Furthermore, *C. africana, Ficus spp.,* and *M. ferruginea* are popular shade trees widely believed to enhance productivity in the enset-coffee homegarden systems. Demel Teketay and Assefa Tegineh (1991) have also reported the popularity of *C. africana* and *Ficus spp*. as coffee shades among farmers of Eastern Ethiopia.

Factors influencing abundance of wood

Among the list of variables hypothesized to influence the standing stock of trees in the homegardens, farm size, area of woodlots, altitude and proximity to highways were very important. The volume of wood in farms generally increased with farm size because farmers have better opportunities to grow more trees once they have satisfied their subsistence and cash crop needs. Among farmers owning less than one hectare of land, 32% had woodlots while among those owning more than one hectare of land 55% had woodlots. On the other hand, although the prevalence of woodlots increases with farm size, it is generally, a) the preference of households to grow eucalyptus as a cash crop, b) absence of sufficient wood from other farm locations and c) availability of micro-sites (such as swampy areas) unsuitable to most crops, that determines the presence of woodlots. The total volume of wood in farms as well as the volume per unit area of land increased with the area of woodlots because an increase in the area of woodlots is associated with increased dominance of densely stocked eucalyptus.

Access to major roads has created marketing opportunities for farmers to sell their produce including wood. The stock of wood near highways is low due to two main reasons. First, marketing opportunities led to intensive exploitation of trees in the farms, which resulted in lower standing volume. Second, once the available wood stock has declined, the majority of the farmers tend to grow wood only for their own consumption. This is particularly true to farmers located in areas where cash crops such as chat and pineapple are grown. In these areas, most farmers do not grow trees for income generation although the road access provides them with marketing opportunities. Apparently, these farmers have weighed the relative advantages and decided to grow chat and pineapple as cash crops instead of trees. On the other hand, most farmers in the subsistence crop dominated and highway-access area grow fast growing eucalyptus trees as cash crop. In general, the stock of wood decreases with proximity to highways, but even in road-access areas variation exists in wood stock of farms depending on whether wood is used as a cash crop or not.

The volume of wood increased with altitude. The lower altitudes are warmer and drier and this could result in high evapo-transpiration, and thus low available moisture. It is, therefore, likely that availability of moisture for plant growth would generally increase with increasing altitude within the limits of the study area (1520-2040 m.a.s.l.), and this might contribute to higher woody biomass production.

6.6 Conclusion

The enset-coffee homegardens of Sidama are heavily stocked with trees and shrubs which largely meet the wood consumption needs of the farming community. The average standing stock of wood in the homegardens was 50.4 m^3 (24 m^3 ha^{-1}) with huge variations ranging from 0.1 to 1120 m^3. The density of trees and standing stock varied with the tree growing location types, with boundaries and woodlots having a high stocking per unit area of land. Crop fields, residential and grazing areas, boundaries and woodlots represented 34.8%, 10.5%, 32.0% and 22.7% respectively of the standing stock of the farms. The standing volume of wood per farm and per hectare differed with prototypes from 70.9 m^3 (30.6 m^3 ha^{-1}) to 17.4 m^3 (9.4 m^3 ha^{-1}). The trees scattered inside the farm field are almost entirely native species and are regarded as complementary to crop production. The standing stock of trees also varied widely among sites and households due to socio-economic and ecological factors, particularly farm size, access to highways and altitude.

CHAPTER 7

7. General discussion and conclusion

7.1 Biodiversity in homegardens

Extensive areas of agroforestry homegardens exist in Southern Ethiopia. These systems are characterized by a unique combination of two major perennial crops, enset and coffee. Enset (*Enset ventricosum* (Welw.) Cheesman) is the staple food in the region and coffee (*Coffee arabica* L.) the main cash crop. These crops are grown in an intimate association with a multitude of crop and tree species and livestock in multistorey agroforestry systems. The gardens have evolved from forests, but in some areas homegardens recently developed from grazing lands are also observed.

Like most multistorey agroforestry systems in the tropics, the enset-coffee homegardens of Southern Ethiopia have a high species diversity. In the present study area, the Sidama region, a total of 198 species of cultivated crop (78) and tree (120) species were recorded in 144 households in four Woredas (districts) as shown in Table 7.1.

Table 7.1 Total number of crop, tree and livestock species in the research woredas.

Woreda	Number of farms	Crop species	Tree species	Total plant species	Livestock species
Dara	36	56	72	128	5
Aleta Wondo	48	64	95	159	6
Dale	36	57	94	151	5
Awassa Zurya	24	33	51	84	6
Total area		78	120	198	7

Variation existed in the number of species at Woreda level ranging from 84 to 159. These figures are comparable to most of the other tropical homegardens reported earlier (Table 7.2). These reports generally show that the humid lowland tropics are the richest in species diversity. The high diversity values in these regions could be attributed to more favorable rainfall and temperature conditions. However, it is also due to considerations of all plant species that include ornamentals and sometimes weeds. For instance, Mendez *et* al. (2001), reported a total of 324 plant species in the homegardens of Nicaragua, of which 180 (56%) were ornamentals. Likewise, 219 plant species occurred in one village in West Java of which 60 (27%) were ornamentals. In the present study, only deliberately grown crop species and trees were recorded. If our inventory would have considered all plant species, the results might have been comparable to some of the highest figures reported in the humid lowlands. On the other hand, species richness of Sidama homegardens by far exceeds those reported from similar highland agroecosystems of Eastern Africa, and the low to mid altitude areas of South Asia. In the Sidama area, the average number of plant species per homegarden was 37, with values ranging from 15 to 78.

Table 7.2 Species richness of selected homegardens in the tropics.

Ecological zone	Location	Total nr. of plant species	Average nr. of plants per homegarden	Sources
Humid lowlands	West Java, Indonesia	- 219 plant species (60 ornamentals)	- 56	Soemarwoto, 1987 Soemarwoto and Conway, 1991
	West Java	- 262 plant species (120 food crops and spices; 142 medicinal, ornamental and trees)	- 20.4 (poor) - 21.9 (rich)	Marten and Abdoellah, 1988)
	Balzapote, Mexico	- 338 plant species (62 trees and shrubs)	- n.a.	Alvarez-Buylla *et* al., 1989
	Yucatan, Mexico	- 135 plant species	- n.a.	Rico-Gray *et* al., 1990
	Quintanana Roo, Mexico	- 150 useful plants	- 39	De Clerck and Castillo, 2000
	Nicaragua	- 324 plant species (180 ornamentals)	- 70 (22-106)	Mendez *et* al., 2001
	Santa Rosa , Peruvian Amazon	- 168 plant species	- 35 (18-74)	Padoch and De Jong, 1991
	South Eastern Nigeria	- 137 plant species	- n.a.	Okafor and Fernandes, 1987
Humid lowlands to mid altitudes	Kandy, Srilanka	- 125 plant species (93 usable)	- 46 (37-65)	Perera and Rajapakse, 1991
	Kerala, India	- 66 plant species (55 crop and 11tree species)	- n.a.	Nair and Sreedharan, 1986
		- 127 woody species	- 22	Kumar *et* al., 1994
Highlands	Chagga, Tanzania	- 111 plant species (58 woody and 53 herbaceous)	- n.a.	Fernandes *et* al., 1984
	Bukoba, Tanzania	- 57 plant species	- n.a.	Rugalema *et* al., 1994
	Wolayita & Gurage Southern Ethiopia	- 60 plant species	- 14.4	Zemede Asfaw and Zerihun Woldu, 1997
	Sidama, S. Ethiopia	- *198 crop and tree species*	- *37 (15-78)*	*This study*

In addition to species diversity, a high level of genetic diversity was observed in the two major crops, enset and coffee. A total of 42 enset land races and 24 coffee varieties have been recorded in this study. The homegardens of Sidama have therefore served as important repositories of species and genetic diversity of plants.

Most studies on biodiversity in homegardens focus on vegetation resources only. As illustrated by our study, also animals are present within homegardens. A total of 7 livestock species occur in these systems (Table 7.3). The overwhelming majority of farmers have cows used for the production of milk and butter. Livestock are also sold when immediate cash is required by the household, thus contributing to livelihood security. Oxen, which are widely used for draft power in the cereal-based systems in the north, east and central parts of Ethiopia, are rare in the Sidama area, and land preparation and cultivation is carried out using hoes. Pack animals are very rare, because the density of markets is rather high and farm produce is often transported by humans. In addition to their economic contribution, livestock provides also manure for soil fertility maintenance. When fodder grass is in short the animals are fed with immature thinned-out enset plants, leaves of enset, banana and other plants, as well as crop residues. They in turn provide manure which is vital for increased yield of crops. This illustrates that the Sidama homegardens are closed systems with minimum dependence on external inputs such as fertilizers.

Table 7.3 Percentage frequency and mean number of livestock in the homegarden farms (n=144).

Nr.	Livestock type		Number of owner farm households (%)	Average nr. of livestock
1.	Cattle		89.0	3.8
		. Cows/heifers	87.5	2.6
		. Ox/steer	26.4	0.4
		. Calves	52.1	0.8
2.	Goat		13.9	0.3
3.	Sheep		11.1	0.2
4.	Donkey		4.9	0.1
5.	Horses		0.7	0.01
6.	Mule		0.7	0.01
7.	Poultry		100	5.4

The number of species grown in a farm is an important indicator of diversity. However, from the utility point of view it is not only the richness that matters but also the diversity in functions. A total of 10 functional groups of crops as well as trees and livestock serving different functions are present in Sidama homegardens, and most of them are fairly well represented in each household.

The high diversity of crop, tree and livestock species with different uses and production cycles in these systems,

- allows year-round production of food, wood and a wide range of other products,
- reduces risk of production failure,
- reduces risk of pests and diseases

- increases productivity and output flexibility,
- improves the microclimate and soil conditions.

The presence of different functional groups of crops, trees and livestock in these systems fulfils the dietary and cash requirements of the households, thus enhancing food and livelihood security in the area.

Area share of farm components

The area of the sample farms varied from 0.18 to 7.46 hectares. Land holding as one of the indicators of wealth varied across the different economic groups of farmers with average values of 0.55, 1.46 and 2.75 hectares for the poor, medium and rich farmers, respectively. The weighted mean area of all farms was about 0.90 hectares. Allocation of land for the different farm components (different types of crops, grazing and residential areas, and trees) varied widely between and within sites. The overall average proportional area of these components shows that crop lands account for 82% of the farm areas while grazing and residential lands have a share of 14% (Figure 7.1). Trees are largely grown scattered in crop and grazing lands and also on boundaries. In addition to this, some farms have separate woodlots for trees. On the average, the woodlots shared about 4% of the farm areas. Among the crops, coffee and enset shared about 53% of the total farm area or 63% of the cropland. Together, with the third major crop maize, they account for 67% of the croplands. Vegetables, fruits, beans and sugarcane have low area share across all the sites. On the other hand, crops such as chat, pineapple and sweet potato have low overall average, but they are major crops at some sites and they might not even exist at the others. The area share of major crops varied across the sites due to differences in the socioeconomic and physical environment, and this lead to identification of four different prototypes of the enset coffee homegardens, as listed in Table 7.6.

The perennial nature of the systems, in which crops such as enset, coffee, fruit trees as well as other trees and shrubs share more than 70% of the farmland, contributes to ecological sustainability and stability. The high productivity per unit area of the staple food, enset, enhances the carrying capacity and the economic sustainability of the systems.

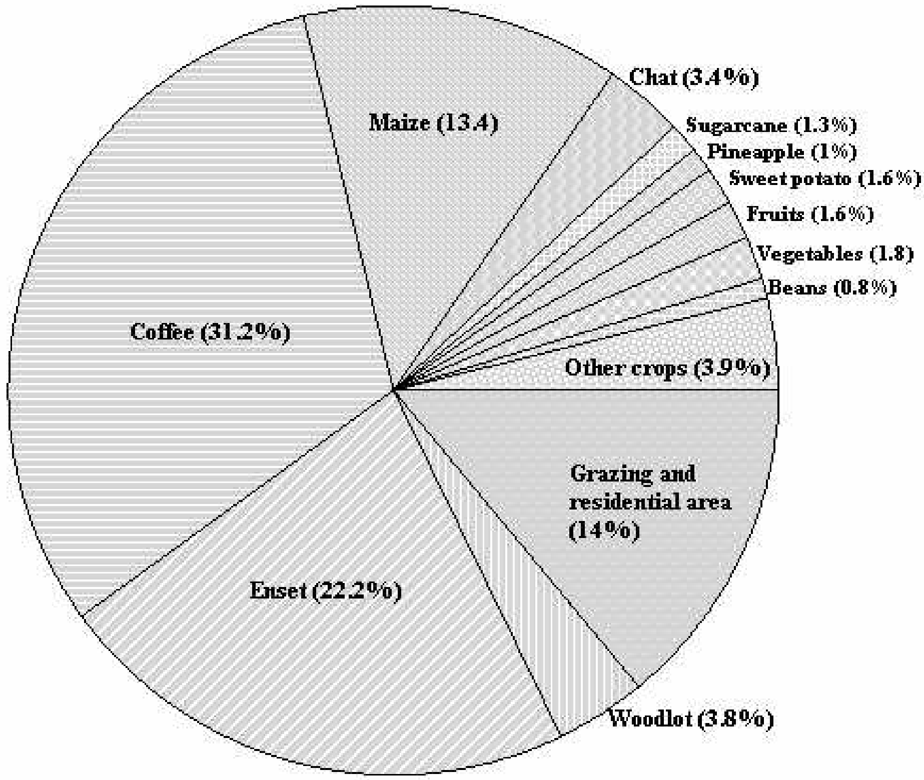

Figure 7.1 Mean area share of the major homegarden components.

Sustainability aspects of the homegardens

Ecological sustainability: The high diversity of species in these systems contributes to genetic conservation of native species, efficient resource use and biological pest control. Also, the perennial nature of the systems together with the high species diversity provides important ecological services such as nutrient recycling, soil and water conservation, and reduces environmental deterioration. These facts indicate the conservation of the resource base, which is vital for future production. Hence, the management of enset-coffee homegardens with high proportion of perennial crops and trees and high species diversity could be regarded as ecologically sustainable.

Socio-economic sustainability: The maintenance of high species diversity in these systems enables year round production of different crops and other products, reduces and spreads risks and expands the amount and quality of labour applied in the farm. In addition to this,

- The high productivity and multiple functions of enset supports a very high population density, which is often 2 to 3 times higher than in the cereal based systems in other parts of the country.
- The large scale production of cash crops such as coffee and chat makes the systems economically viable.
- The systems use locally available internal resources and there is minimal or no dependence on external inputs, and their management is well adapted to the local farming conditions

Therefore, the enset-coffee agroforestry homegardens of Southern Ethiopia can be considered as socioeconomically sustainable production systems. However, the recent development in expansion of monoculture plots of food and cash crops such as maize, sweet potato, chat and pineapple in these systems is likely to affect their long-term sustainability.

7.2 Factors influencing diversity and composition of species in homegardens

The results of multiple linear regression of species richness and composition of homegardens have been presented in the previous chapters. The major factors that influence species richness and area share of the homegarden components are briefly discussed.

Effects on species richness

The size of the farm (homegarden) and its proximity to major roads affect tree and livestock species richness of farms (Table 7.4). Both factors did not affect crop species richness. Farmers with small land holding grew the same number of crop species as the large holders, but with increasing land holding farmers increased the number of tree species. The number of livestock species and total number of livestock also increased with farm size. Thus, the decline in farm size is likely to affect the species richness in trees and livestock.

Proximity to roads also affected species richness in trees and livestock. Farmers close to markets grew the same number of crops but the number of tree and livestock species was low. The roads have effectively linked the farms with the external markets. Access to roads has enabled farmers to grow more of new cash crops and this has affected the area required for trees and grazing, eventually reducing the richness in species. In some road-access sites farmers use trees as cash crop, but only few species, mainly eucalyptus are sold. The proximity of farms to markets had a negative effect on crop species richness. Farmers close to markets grow a slightly lower number of crop species because the market access encourages them to focus on production of marketable products and to purchase products for consumption.

Farm size is an important element in influencing diversity and composition of tree species, but the density of persons per farm (number of inhabitants per hectare of farm land) should also be considered as it indicates the magnitude of land pressure. Density of persons in the farm has affected negatively species richness of crops and trees. This is justifiable because when land is increasingly scarce, farmers tend to focus on few staple food crops.

Table 7.4 Summary of results of multiple linear regression of species richness, volume of trees and number of livestock on physical and socio-economic environments.

Factors	**Species richness**			**Standing Volume of trees/ha**	**Nr. of livestock (TLU)**
	Crops	***Trees***	***Livestock***		
Adjusted R^2	0.15***	0.53***	0.11***	0.49***	0.48***
Physical environment					
- Altitude (1520-2040 m.a.s.l.)	ns	ns	ns	0.15*	0.19*
- Slope (0-45%)	ns	0.14*	ns	ns	ns
Socioeconomic environment					
- Distance to markets (0.04-6.0 kms)	0.17*	ns	ns	0.13*	ns
- Distance to highway (0.02-26 kms)	ns	0.35***	0.17*	0.34***	ns
- Farm size (0.18-7.46 ha)	ns	0.42***	0.28***	0.15*	0.48***
- Farm labor force (2-12)	0.18*	ns	ns	ns	ns
- Population density (Inhabitants/ha of farmland) (2-35)	-0.20*	-0.17*	ns	ns	ns
- Involvement in off-farm work (yes/no)	ns	0.14*	ns	ns	ns

Effects of area share of major crops

Socio-economic and physical environment factors also influence the area share of species. Often, the same factor has an opposite effect on the cash crop coffee and the food crops enset and maize (Figure 7.2). The area share of cash crops increased with farm size but that of food crops declined because subsistence needs could be met from an increasingly smaller proportion of land. Accordingly, the area share of enset decreased and that of coffee increased. However, in areas that have access to highways and external markets, the share of this traditional cash crop is being reduced by other cash crops such as chat. Farm size has a positive effect on the standing volume of trees per hectare. This is because large holders can grow trees to bigger dimensions and allocate separate woodlots to trees. This finding agrees with earlier reports (Kumar *et* al., 1994; Biggelaar and Gold, 1996, Mendez *et* al., 2001). Large farms also had more livestock and more livestock species mainly because of the presence of sufficient grazing land and or fodder.

Access to roads, in particular, has greatly affected the area share of the major crops. In road-access areas, farmers produced more chat and pineapple for the external market by reducing the area of coffee. Both chat and pineapple should be sold fresh, and the road access has enabled the farmers to produce these crops for the market. Among the food crops, the area share of enset decreased by road access, and the share of maize increased. Farms close to the roads grew more maize because they allocate a significant portion of their land to cash crops. Such responses of farmers towards market opportunities have also been reported in earlier studies by Wiersum (1982), Marten and Abdoellah (1988), Soemarwoto and Conway (1991) and Kaya *et* al. (2002).

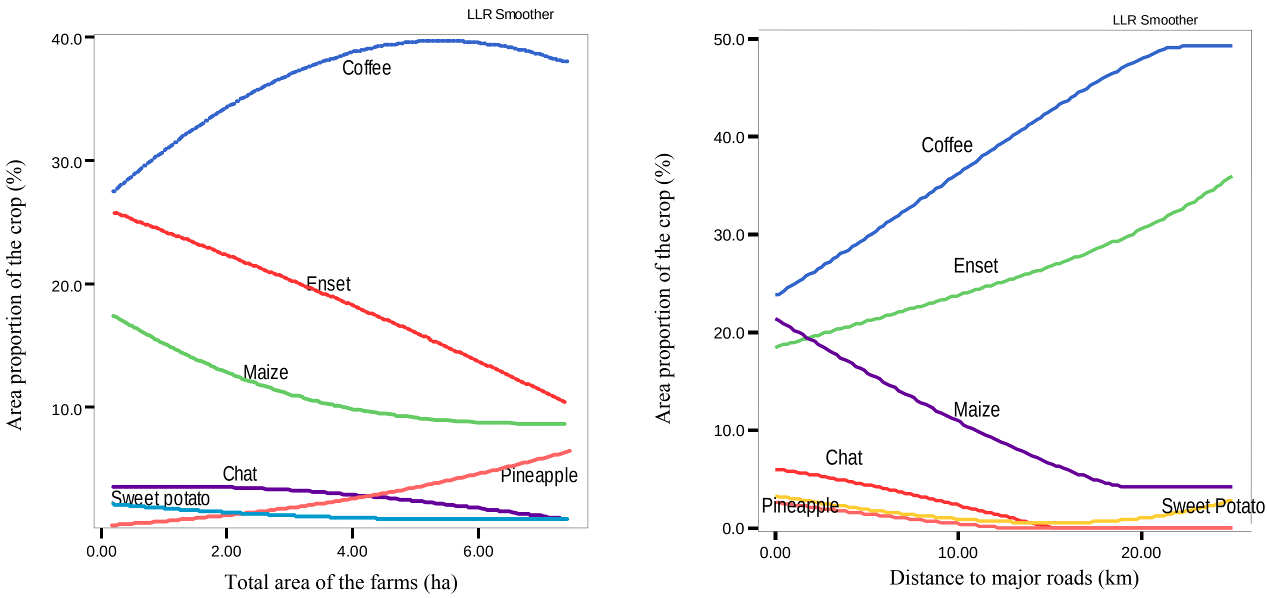

Figure 7.2 The relationships of farm size (a) and access to major road (b) with area share of the major crops.

The area share of enset increased with altitude. In the warmer and relatively drier low altitude sites farmers grew more of other food crops such as sweet potato. Altitude also affects negatively the area share of sweet potato and pineapple. The overall share of the two crops in these systems is low, but they are very important at the warm, low altitude sites (1520-1750 m.a.s.l.) where they thrive very well. Pineapple is more dominant at the sites where low-altitude and access to road are combined.

In addition to the crops, farm size and access to road have heavily influenced the composition and standing stock of trees. The density and standing stock of the dominant native timber and other multipurpose species such as *Podocarpus falcatus, Cordia africana* and *Milletia ferruginea* decreased with decreasing farm size and increasing access to road. On the other hand, the share of fast growing eucalyptus species increased to produce wood for home consumption as well as for income generation.

Main hypotheses

It was hypothesized that some socio-economic and physical factors affect the diversity and composition of species in homegardens among which farm size and access to market and road were considered to play a significant role (Figure 1.5 in chapter1).

A decrease in farm size affected negatively the species richness of trees and livestock, standing volume of trees, number of livestock and area share of cash crops. Small-holder farmers attached priority to producing food crops mainly annuals. The agroforestry homegardens of Southern Ethiopia already carry a very dense population, which is still growing fast. The high population growth (2.2%) is likely to lead to increased fragmentation of farmlands. The increasingly smaller farms would in turn result in reduction of the perennial components (crops and trees) and livestock which are vital for the sustenance of the systems. Thus, additional measures such as job creation and population control need to be taken in addition to improving the productivity of the systems.

Proximity to major roads also had similar effects. Richness in species of trees and livestock, and standing volume of trees decreased with increasing access to highways. Also the share of annual crops mainly maize, and that of new cash crops, chat and pineapple increased, while the traditional cash crop coffee declined. The share of native and ecologically friendly multipurpose trees declined with road access and that of eucalyptus increased. In general, the share of the perennial crops and native tree species that are considered to play a significant role towards the stability of the systems declined with proximity to highways. Roads are important for rural development and thus more roads are likely to be constructed in the future that will link these areas with external markets. Therefore, attempts should be made to maintain the perennial basis which is responsible for the sustenance of the systems. Research should also focus on integration of expanding cash crops (such as chat and pineapple) into the systems without changing the multi-storey structure. The future of these homegardens depend on the maintenance of enset based staple food production, because of it has high productivity, different end uses and wide ecological roles. Thus, strategies should be developed to reverse the increasing dependence on maize and enhance the production of enset.

7.3 Prototypes of the enset - coffee homegarden agroforestry systems

The variation in area share of major crops across the sites has lead to identification of different prototypes of the enset coffee homegardens. Among the factors that resulted in the development of these prototypes, the site's access to a highway and its altitude have been the most important. Based on similarities in average area share of major crops at site level, the 12 sample sites (Peasant Associations) can be grouped in to four sub systems. Among farms within each site, variation exists in area share of crops mainly due to differences in farm size, but this classification is based on average area share of the major crops at the site (PA) level. In the following, the area share, diversity and productivity of the different prototypes are compared.

Most of the homegardens fall under the original type enset-coffee-maize prototype, in which coffee and enset alone account for about 65% of the farm land (Table 7.5). These sites are located far from major roads. In this category, enset and maize are the main staple food crops. Coffee is the main cash crop. Species richness is among the highest with an average of 41 cultivated crop and tree species (Table 7.6). The standing stock of trees is the highest with an average wood volume of 30.6 m^3 per hectare of the gardens.

The enset-coffee-maize-sweet potato prototype is predominantly subsistence oriented. The share of the staple crop, enset is low and thus farmers had to produce more maize and sweet potato to ensure availability of food. It has the highest species richness of crops and trees. Cash crops have a low coverage, and thus some farmers produce eucalyptus for income generation. The other two prototypes, which are located close to the highway, are cash crop oriented. The enset-coffee-maize-chat systems are characterized by large proportion of chat (14%) and the lowest share for coffee (11%). They have the highest population density and thus, enset production has to be supplemented with a higher proportion of maize (29%). Diversity of plant species is the lowest (25).

Table 7.5 Area share of the major crops at the different prototypes

Prototype	Graz. & residence	Wood lot	Enset	Coffee	Maize	Chat	Sweet potato	Pine-apple	Persons/ hectare
Enset-coffee-maize (n = 84)	14.2 [b]	4.6	24.7 [a]	39.8 [a]	9.2 [b]	0.5 [c]	0.8 [c]	0.2 [b]	8.8 [ab]
Enset-coffee-maize-sweet potato (n=12)	21.8 [a]	4.3	13.3 [b]	21.8 [c]	26.7 [a]	0.6 [c]	7.0 [a]	0.0 [b]	8.0 [ab]
Enset-coffee-maize-chat (n=24)	19.5 [ab]	4.1	19.7 [ab]	10.6 [d]	29.4 [a]	13.6 [a]	0.3 [c]	0.0 [b]	10.8 [a]
Enset-coffee-maize-chat-pineapple (n=24)	7.4 [c]	1.5	21.7 [ab]	30.1 [b]	13.5 [b]	5.8 [b]	4.4 [b]	8.5 [a]	6.1 [b]
Mean (n=144)	14.6	4.0	23.1	32.5	14.0	3.5	2.6	1.1	8.6
	P<0.001	ns	P<0.01	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	ns

In these systems, the number of livestock per farm is the highest (3.4) and this could be attributed to the higher farm income of farmers which enables them buy cows and feed to produce milk for home consumption and the market. The enset-coffee-maize-chat-pineapple subsystems accommodate a relatively balanced proportion of the different major crops. The major food crops enset, maize and sweet potato shared about 40% of the farm area while the share of the cash crops coffee, chat and pineapple is about 44%. One of the other peculiarities of this sub system types is the lowest area share of grazing and residential lands, and the highest proportion of croplands. The standing stock of wood is also the lowest.

Table 7.6 Mean number of plant species (crop and tree), livestock species, standing stock of wood and number of livestock at the different prototypes

Prototypes	Number of crop and tree species		Number of livestock species		Standing volume wood ha^{-1}.		No, of livestock/TLU ha^{-1}	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Enset-coffee-maize (n=84)	41[a]	12.3	2.3[a]	0.9	30.6	28.2	2.1[b]	1.9
Enset-Coffee-maize-sweet potato (n=12)	43[a]	12.2	2.0[a]	0.4	20.1	27.6	1.9[b]	1.0
Enset-coffee-maze-chat (n=24)	25[b]	5.6	2.1[a]	0.7	17.5	18.1	3.4[a]	3.6
Enset-coffee-maize-chat-pineapple (n=24)	30[b]	7.9	2.2[a]	0.6	9.5	8.1	1.7[b]	1.6
Mean (n = 144)	37	12.0	2.2	0.8	24.0	25.5	2.2	2.2
F-test (P)	*< 0.001*		*ns*		*< 0.01*		*< 0.05*	

Productivity of the prototypes

Preliminary assessments were carried out to compare the productivity aspects of the four prototypes. This was carried out by collecting farm-level data on the yield of the different components. In these assessments

- The annual yield of crops for each farm was collected and then converted to monetary value by using average price levels. In the calculation, only the main product of each crop is considered.
- The annual volume of livestock products (milk, butter and eggs) for each farm were multiplied by the average price. Farmers sell livestock whenever necessary, but the value of the livestock themselves is not considered in this calculation.
- The standing volume of wood was divided in two tree categories: High value timber species (eg. *Podocarpus falcatus*, *Cordia africana*, *Aninigeria* spp. etc.) which have a long rotation cycle, and low value wood species, used for construction posts (Eucalyptus) and fire wood, mainly grown in short rotations. Then annual income from the trees was then calculated by taking into account the rotation cycle and the respective value of each cubic meter of wood.
- As farm inputs are hardly used in these systems, the calculations are based on non-external input conditions.

The results of gross annual farm income estimates (Table 7.7) show that the crop components contribute to an average of 89% of the total farm income. Livestock and trees contributed to 9 and 2%, respectively. In addition to their products, livestock also provide manure that is vital for soil fertility maintenance. The economic contribution of trees appeared to be the lowest, but their ecological roles (which are not assessed here) are perhaps the most important in terms of maintaining stability of the systems.

Table 7.7 Mean gross annual farm income of the different prototypes

Prototype	Monetary value (birr)				Birr/	Birr/
	Crops	Livestock products	Trees	Total	hectare	capita
Enset-Coffee-Maize (n= 84)	8072	980	432	9484	***5118***	738
Enset-Coffee-Maize-Sweet potato (n=12)	4517	758	134	5409	***4216***	637
Enset-Coffee-Maize-Chat (n=24)	7753	772	197	8722	***7519***	951
Enset-Coffee-Maize-Chat-Pineapple (n=24)	12118	779	123	13020	***7146***	906
Mean (n=96)	8115	823	222	9159	***6000***	808

Note: 1 Ethiopian Birr = ±0.10 Euros

Yield per unit area and time of the major crops, enset and coffee is higher at the basic enset-coffee-maize prototypes, but gross annual farm income is highest at the prototypes that have included the other cash crops, chat and pineapple, with annual revenues exceeding Birr 7000.00 per hectare. The subsistence oriented, enset-coffee-maize-sweet potato systems had the lowest revenue per hectare. Thus, the prototypes where chat and pineapple are grown as major crops are economically the most

attractive. It should, however, be understood that in such subsistence agricultural systems, by-products play very important roles. For instance, enset provides fodder, fiber, lining and packing material, medicine, etc., in addition to food. Some of these products are even sold in the market. Our calculation has considered only the food component and thus it underestimates the contribution of enset, especially in the enset-coffee-maize systems which have the highest share of enset.
The gross annual farm income figures give only a global indication of the economic performance of the different prototypes. As data on production costs and on the value of all major farm outputs were not available and could not be collected within the framework of this thesis, the profitability of the system could not be assessed.

Overall effects of the increasing share of new cash crops

The shift from the traditional enset-coffee-maize systems towards inclusion of other cash crops has definitely diversified and increased farmers' income. However, this change has not only affected the composition of species, but also the structure and plot-level diversity of the systems. First, the share of the two basic crops, enset and coffee has decreased in the new prototypes. The study on species diversity of the different farm units (chaper 3) has shown that enset and coffee plots (units) are the richest in species and structurally the most complex. On the other hand, the number of crop and tree species associated with the new cropping units is low, thus plot level diversity is lower. In these systems, the share of maize has increased tremendously because the production from enset is not sufficient to feed the households. As maize demands more light, it is grown on spots that have minimum shade or no shade at all. Pineapple and chat are also grown with minimum or no shade. The increase in area share of these crops is therefore associated with reduction in complexity and multistorey structure of the systems. The diversity and standing stock of trees is also low in the new prototypes. The decline in the area share of enset and coffee, and their replacement with monoculture plots of the above crops could reduce the ecological benefits derived from the integrated and complex systems, and threaten their long-term sustainability. Therefore, attempts should be made to integrate these crops into the existing multi-storey systems.

7.4 General conclusions and recommendations

The diversity of crops, perennial nature of the systems, particularly the combination of the basic crops enset and coffee, the high diversity and standing stock of trees and presence of livestock, and the interaction between these components have been the most important reasons for the stability of the enset-coffee homegardens.

The crop components include the staple food crops enset and maize, other food crops such as sweet potato and vegetables, the cash crops coffee, chat and pineapple and other crops fulfilling the different needs of farmers. Crop residues and pruned leaves of crops such as enset and banana are important sources of fodder, particularly in the dry season. The life cycle of most of these crops is different, which makes food and other products available throughout the year. The presence of crops with different functions fulfils the nutritional and monetary needs of the households. The basic food crops, enset and maize, which are rich in carbohydrates are supplemented by pulses, vegetables, fruits and animal products that provide proteins, fats and vitamins. This contributes to a balanced dietary composition. The income from cash crops contributes to fulfillment of material and other needs of the farm families.

Among the crops, enset and coffee have the most significant economic and ecological roles. Enset serves as shade to most crops including coffee. It is a very high yielding food crop and provider of different products such as fiber, fodder, as well as wrapping and construction materials that fulfil the different needs of the farming community. These attributes make enset a suitable crop for low-input sustainable agricultural systems. Coffee provides shade to the lower canopy crops and it protects the soil. The harvest of berries removes only a small portion of the biomass and hence it doesn't cause heavy soil mining. Economically, coffee is the principal source of income. Moreover, the processing and marketing of coffee creates employment for many people thereby making significant contributions to the regional and national economy. The combination of these two native perennial crops and their dominance in the systems therefore contribute to socioeconomic as well as ecological sustainability of the systems.

Trees have various socio-economic and ecological roles. They provide households with wood, food, fodder and cash. Almost all firewood demand of the households is met with trees from these homegardens. Wood is the most important material used in the construction of houses, fences and shelters. Different types of furniture, farm tools, tool handles and household utensils are also produced from wood. Trees are important sources of income. Tree species such as *Podocarpus falcatus* and *Cordia africana* are important timber species widely marketed in the region. Eucalyptus poles and posts are also widely marketed for construction of houses. Thus, trees from these farms not only generate income to farmers, but also contribute to the regional economy. The ecological contribution of trees in these systems is also widely acknowledged. Many species of native trees such *as Cordia africana, Milletia ferruginea, Ficus* spp. etc., are grown extensively inside crop fields because of their roles in providing shade and mulch, control of erosion and in the improvement of microclimate. Livestock, especially cows provide protein that is necessary to supplement the carbohydrate-rich enset diet and animal manure which is vital for maintenance of soil fertility.

In general, these integrated agroforestry systems contribute to control of pests and diseases, control of erosion, amelioration of microclimate, and maintenance or enhancement of soil nutrient levels. As a result, these systems are less dependent on external inputs. The high yield of enset as a food crop, the income from coffee and the stability of the system explain why the enset-coffee homegardens have been supporting a very dense population of 370 to 560 persons per square kilometers.

Improved access to urban markets has lead to the decline in the areas of enset and coffee and also trees. The decline in the share of these perennial components and their replacement particularly with annual crops reduces the ecological benefits derived from these integrated and complex systems. This in combination with a reduction of farm size as a result of poulation growth threatens their long-term sustainability.

Attempts to improve these homegardens should not affect the integrated nature of the systems. To this effect, research and extension efforts should aim at developing techniques how to integrate new crops into the systems without affecting their integrity. An example in this regard is the dissemination of coffee varieties that are resistant to Coffee Berry Disease (CBD). Different CBD resistant coffee varieties that are developed by the Ethiopian Agricultural Research Organization are being widely planted by farmers replacing susceptible ones. Most of the new varieties give a high yield and they have manageable size, adding to their acceptability by farmers. Obviously such changes contribute to improved performance of the systems.

Likewise, improvements can be made in other components while maintaining the diversity and complexity of the vegetation. For instance, most of the fruit trees such as avocado, guava, papaya, white sapote and mango are giant trees bearing few fruits. Research and extension efforts should aim at introducing high yielding and high quality varieties that could improve productivity and returns of the systems. Since the enset diet is rich only in carbohydrates, efforts should be made to introduce or expand high yielding pulses and vegetable crops. This would further enhance the nutritional well-being of the people while improving the efficiency of the systems. Another suitable intervention might be the planting of nitrogen fixing leguminous trees with good timber quality.

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Summary

In the highlands of Southern Ethiopia extensive areas of agroforestry homegardens occur. These systems are characterised by a unique combination and dominance of two native perennial crops, enset and coffee. Enset (*Enset ventricosum* (Welw.) Cheesman) is the major staple food while coffee (*Coffea arabica L.*) is the principal cash crop. In addition a large variety of staple food crops, vegetables and tree crops are present. Unlike most homegardens which are small and supplementary food production units, these homegardens are extended farm fields around houses and they form the principal means of livelihood for the farming households.
Homegardens are important agricultural systems and occur everywhere in the tropical world. These traditional small-holder farming systems are changing rapidly due to increasing population pressure on the land, the introduction of new agricultural technologies, new opportunities for agricultural markets and an increasing need for cash earnings. In several places this traditional subsistence agriculture, generally based on diversity of crops, is changing into a market-oriented agriculture based on few crops only.

The present study aims at characterizing the diversity and the composition of the species in these enset-coffee agroforestry homegardens and at identifying the factors that affect the dynamics in their composition. It attempts to assess the implications of the changes in these homegardens for agricultural sustainability.
The main research questions of the study are:

1. What is the diversity, composition (area share) and productivity of crops at farm and regional levels, what land use changes are occurring, which farm types can be distinguished and what factors influence farm-level crop species diversity and area share of major crops?
2. What is the diversity, density, composition and standing stock of trees at farm and regional levels, and which factors influence them?
3. What is the productivity of different homegarden types?
4. What conclusions can be drawn from the above information with respect to agricultural sustainability?

The study was conducted in Sidama, southern Ethiopia. This area is considered representative for the enset-coffee agroforestry homegardens. In order to get a good representation of the area and their systems in total 4 districts (woredas) with 12 peasant associations (administrative villages) and 144 farms were selected (12 farms, representing households with different resources, per association). At district and association level, information was gathered on environmental factors (climate, soil, altitude) and on socio-economic factors (population density, market structure) through interviews, reconnaissance surveys and literature studies. At farm level information was gathered for the whole farm and for individual plots, using measurements, interviews and observations. Information was collected on crop composition, abundance and yield, tree composition and abundance, altitude and slope, and on socio-economic situation (distance to markets and major roads, household characteristics) per farm.

Overall a total of 78 cultivated crop species have been recorded in these systems among which 13 occur in 50% of the farms. Each homegarden had an average of 16 crop species. Enset, coffee and

maize are frequent and abundant across all homegardens, but their area share varies across sites and among households. Enset and coffee together cover about 63% of the crop area, maize covers 16% and the remaining 75 crop species together cover only 21%. This uneven distribution in abundance of the species has resulted in a low uniformity (evenness) in their composition.

Crop diversity is not evenly distributed across the different plots (units) observed in the homegardens. Plots of coffee and enset were found to be associated with a high number of crop species and thus contributing to high species richness of the gardens. The number of crop species grown in a farm is an indicator of diversity. However, from the utility point of view the heterogeneity in functional groups of crops is important in order to fulfil the dietary and cash requirements of the households. In this respect, a total of 10 functional groups of crops were recognized each represented by 3 to 15 species of crops, and an average of 8.1 groups were found in each farm. The basic food crops, enset and maize, which are rich in carbohydrates are supplemented by pulses, vegetables, fruits and animal products that provide proteins, fats and vitamins.

Based on the share of the major crops of the farms, four homegarden prototypes were distinguished: Enset-Coffee-Maize (84 farms), Enset-Coffee-Maize-Sweet potato (12), Enset-Coffee-Maize-Chat (24) and Enset-Coffee-Maize-Chat-Pineapple (24 farms).

Variation among sites (peasant associations) in both prototypes and crop species is large and is largely explained by geographical location and altitudinal differences. At some sites the share of the basic crops, enset and coffee has decreased significantly over the last years, because these crops have been replaced by new cash crops like chat and pineapple, or food crops like maize and sweet potato. The recent changes in land use have been triggered by improved marketing opportunities (cash crops) and shrinking land holdings (food crops). Productivity per unit area of crops was higher for the prototypes where the share of enset and coffee is high. Monetary output per unit area of land, however, was higher for prototypes with introduced new cash crops.

Access of farms to market and major roads had a significant effect on most farm composition and structure indices used. Crop species richness increased with distance of farms to markets, but evenness (uniformity in abundance) decreased. Homegardens close to markets grow fewer crop species because they give priority to marketable products. Close to markets, the share of coffee decreased while that of chat and maize increased. Access to major roads (highways) has linked the farms with external markets and thus in homegardens close to the roads farmers produced more new cash crops, and less enset and coffee, while the production of maize has increased. These land use developments have also changed the structure of the systems: the expanded crops (chat, pineapple, maize and sweet potato) are largely grown in monoculture plots. The characteristically integrated multistorey systems thus are gradually changing to a mosaic of patches of monoculture plots that have only one or two storeys. The expansion of cash crops in the systems is economically attractive in the short term, but the disintegration of these multistorey, perennial-crop-based systems into monoculture plots could negatively affect the stability and resilience associated with their complexity. Attempts should therefore be made to integrate the new crops into the existing systems without changing its multistorey structure.

A total of 120 tree and shrub species were recorded, and an average of 21 species in each farm. The species *Cordia africana, Eucalyptus camaldulensis, Milletia ferruginea* and *Euphorbia candelabrum* occurred in more than 88% of the farms. The first two species together with *Podocarpus falcatus* are the most abundant trees (61% of the tree population). The total population of trees per farm averaged 855 (475 per ha). The high tree density is due to presence of closely-spaced eucalyptus trees which, because of their highly competitive effects, are planted on farm boundaries and in separate woodlots. Trees scattered inside the farms are mainly native species such as *C. africana* and *M. ferruginea*, which farmers regard to be complimentary to crop production.
Tree diversity was not evenly distributed across the different plots in the farms. Coffee plots have the highest number of associated tree species followed by enset plots and woodlots. Plots of the newly expanding crops such as chat, pineapple, sweet potato and maize have few associated tree species, since shade trees are deliberately reduced or avoided.

The four homegarden prototypes differed clearly in the composition of tree species, which reflects the light requirements of the dominant crops and the prevailing physical and socio-economical conditions. Farm size, woodlot area and road access affected both diversity and density of trees. Tree species richness of farms increased with size and remoteness of farms. Density of trees increased with woodlot area but evenness (uniformity in abundance) of tree species decreased because woodlots are dominated by densely stocked eucalyptus. Access of farms to major roads was associated with few tree species and a low tree density but a higher evenness because farms closer to the roads focused on commercial crops.

The average wood standing volume per homegarden was 24 m^3 ha^{-1}, with a large variation across sites and individual farms. At boundaries and in woodlots, trees are densely stocked, but inside crop fields and grazing lands they are sparse. These sparse trees have much wood, however: some 31% of the standing wood volume occurred in scattered trees while 69% was grown on boundaries and woodlots. Wood volume varied widely among sites and households due to ecological and socio-economic factors, particularly altitude, access to road and farm size.

The major findings of the study are synthesized in the last chapter. A total of 198 cultivated plant species and 7 livestock species were recorded in these systems. The diversity of crops, the perennial nature of the systems, the high diversity and standing stock of trees, the presence of livestock, and the interaction between the components are suggested to be the most important reasons for their sustainability and stability.
The presence of different functional groups of crops in these systems fulfils the nutritional and monetary needs of the households. Among the crops, enset and coffee have the most significant economic and ecological roles. Enset is a high yielding food crop and provider of various products and is thus a suitable crop for low-input sustainable agriculture. Coffee provides the principal source of income and its processing and marketing creates employment for a large number of people, thereby making a significant contribution to regional and national economies. The combination of these two native perennial crops and their dominance in the systems therefore contributes to socio-economic and ecological sustainability. Trees provide households with wood, food, fodder and cash. Moreover, they play important ecological roles (provision of shade and mulch, nutrient recycling, soil and water conservation and improvement of microclimate) which

contribute towards the stability of the systems. Livestock provide protein and cash but they also generate manure that is vital for maintenance of soil fertility.

Recent trends in land use changes that result from increasing commercialization and land pressure have lead to the decline in the areas of enset, coffee and trees. The decline in the share of these perennial components and their replacement particularly with annual crops could adversely affect the ecological benefits derived from these integrated and complex systems and threaten their long-term sustainability. Therefore, attempts to improve these homegardens should not affect their integrated nature. In this respect, research and development efforts should aim at developing techniques on how to integrate high value crops into the systems without affecting their integrity.

Samenvatting

In de hooglanden van zuidelijk Ethiopië komen agroforestry erftuinen veelvuldig voor. Deze systemen worden gedomineerd door een unieke combinatie van twee meerjarige gewassen: enset en koffie. Enset (*Enset ventricosum* (Welw.) Cheesman) is het voornaamste basisvoedingsmiddel, koffie (*Coffea arabica* L.) is het voornaamste handelsgewas. Daarnaast is er een grote variatie aan basisvoedingsmiddelen, groenten en boomgewassen. In tegenstelling tot de gangbare erftuinen, waar slechts op kleine en aanvullende schaal voedsel wordt geproduceerd, bestaan deze erftuinen uit grote velden rond de huizen en vormen ze de belangrijkste bron van levensonderhoud voor de boeren huishoudens.
Erftuinen zijn belangrijke landbouwsystemen die overal in de tropische wereld voorkomen. Deze traditionele systemen veranderen snel als gevolg van een toenemende populatiedruk op het land, de introductie van nieuwe landbouw technologieën, nieuwe mogelijkheden voor landbouwmarkten en een toenemende vraag naar geldelijke inkomsten. Op veel plaatsen verandert deze traditionele landbouw voor eigen gebruik, gebaseerd op een veelheid van gewassen, in een marktgeoriënteerde landbouw gebaseerd op slechts enkele gewassen.

Deze studie heeft tot doel de diversiteit en samenstelling van de soorten in de enset-koffie erftuinen van zuidelijk Ethiopië in kaart te brengen en de factoren die de dynamiek in deze samenstelling sturen, te identificeren. Er wordt gepoogd de gevolgen van de veranderingen in deze erftuinen voor de duurzaamheid van de landbouw in te schatten. De belangrijkste onderzoeksvragen zijn:

1. Wat is de diversiteit, samenstelling (aandeel in het areaal) en de productiviteit van gewassen op bedrijfs- en regionaal niveau, welke veranderingen vinden plaats in het landgebruik, welke bedrijfstypen kunnen worden onderscheiden en welke factoren beïnvloeden de diversiteit aan gewassen en het aandeel in het areaal van de belangrijkste gewassen op bedrijfsniveau?
2. Wat is de diversiteit, de dichtheid en samenstelling van bomen op bedrijfs- en regionaal niveau, en welke factoren beïnvloeden deze?
3. Wat is de productiviteit van de verschillende typen erftuinen?
4. Welke conclusies kunnen worden getrokken uit bovenstaande informatie aangaande de duurzaamheid van de landbouw?

De studie is uitgevoerd in Sidama, zuid Ethiopië. Dit gebied is representatief voor de enset-koffie erftuinen. In totaal zijn 4 districten (woredas) bestudeerd, met 12 boerendorpjes elk en 12 verschillende boerenhuishoudens per dorpje (totaal 144 huishoudens). Op districts- en dorpsniveau is informatie verzameld over omgevingsfactoren (klimaat, bodem, altitude) en over socio-economische factoren (populatie dichtheid, markt structuur) door interviews, verkenning surveys en literatuur studie. Op het niveau van de huishoudens is informatie verzameld over het hele huishouden en over individuele velden: samenstelling, aantal en productie van gewassen, samenstelling en aantal bomen, altitude en helling. Tevens zijn voor elk huishouden gegevens over de socio-economische situatie verzameld, alsmede de afstand tot de markt and tot belangrijke wegen.

In totaal zijn 78 gecultiveerde gewassen aangetroffen in deze systemen, onder welke 13 voorkomen in 50% van de boerderijen. Gemiddeld werden in elke erftuin 16 gewassen verbouwd. Enset, koffie

en maïs zijn algemeen, maar hun aandeel in het areaal varieert tussen gebieden en tussen huishoudens. De bovengenoemde drie gewassen komen niet alleen vaak voor, maar ook in grote hoeveelheden. Enset en koffie hebben samen al een aandeel van 63% in het areaal, maïs bedekt 16%, en de overige 75 gewassen bedekken samen slechts 21% van het areaal. Deze ongelijke verdeling in voorkomen van de soorten heeft geresulteerd in een lage uniformiteit in hun samenstelling.
De diversiteit aan gewassen in de erftuinen was niet gelijk verdeeld over de verschillende percelen. Percelen met koffie en enset bevatten ook een groot aantal andere gewassoorten, en dragen derhalve bij aan een grote soortendiversiteit van de erftuinen. Het aantal gewassoorten dat wordt verbouwd op een boerderij is een indicator voor de totale diversiteit. Vanuit het gebruikersoogpunt is de diversiteit aan functionele groepen van gewassoorten belangrijk voor de inkomsten en voedingsbehoeften. In totaal zijn in deze studie 10 verschillende functionele groepen onderscheiden, die elk bestaan uit 3 tot 15 gewassen. Gemiddeld werden per boerderij 8.1 groepen aangetroffen. De basisvoedselgewassen, enset en maïs, die rijk zijn aan zetmeel worden aangevuld met bonen, bladgroenten, fruit en dierlijke producten die zorgen voor eiwitten, vetten en vitaminen.

Vier prototypen erftuinen zijn onderscheiden, gebaseerd op het aandeel van de belangrijkste gewassen: Enset-Coffe-Maize (84 huishoudens), Enset-Coffee-Maize-Sweet potato (12), Enseet-Coffee-Maize-Chat (24) en Enset-Coffee-Maize-Chat-Ananas (24 huishoudens).

Variatie tussen dorpen in zowel prototypen als soorten gewassen is behoorlijk groot en wordt voornamelijk verklaard door verschillen in geografische locatie en altitude. Op sommige plaatsen heeft een deel van de belangrijkste gewassen -enset en koffie- plaatsgemaakt voor nieuwe handelsgewassen zoals chat en ananas, of voedselgewassen als maïs en zoete aardappel. De recente veranderingen in het landgebruik zijn het gevolg van verbeterde toegang tot markten en afgenomen landbezit. De productiviteit per oppervlakte eenheid bleek hoog binnen de prototypes waar het aandeel van enset en koffie heel groot is. Echter, geldelijke inkomsten per oppervlakte eenheid land was hoger voor prototypes waarin nieuwe handelsgewassen zijn geïntroduceerd.

Toegang van boerenbedrijven tot markten en grote wegen had een significant effect op de diversiteit en soortensamenstelling. De soortenrijkdom nam toe naarmate de afstand van de boerderijen tot de markten toenam, maar de uniformiteit (gelijke verdeling van de gewassen) nam af. In erftuinen dichtbij markten werden minder gewassen verbouwd, omdat men zich concentreerde op producten bestemd voor de markt. De toegang tot grote wegen verbond de huishoudens met externe markten en als gevolg daarvan produceren boerderijen vlakbij grote (snel)wegen meer nieuwe handelsgewassen ten koste van koffie en enset. Maïs is op deze locaties belangrijker geworden. Deze ontwikkelingen in het landgebruik hebben niet alleen het areaal aan gewassen veranderd, maar ook de structuur van deze systemen. Gewassen zoals chat, ananas, maïs en zoete aardappel worden nu op bepaalde percelen voornamelijk in monocultuur verbouwd. De overgang naar het verbouwen van meer handelsgewassen is op de korte termijn een aantrekkelijke optie. Echter, het ombuigen van een geïntegreerd, gemengd systeem naar een systeem gebaseerd op monocultuur kan een bedreiging vormen voor de stabiliteit en de veerkracht van het systeem. Daarom moet worden gepoogd de nieuwe handelsgewassen te integreren in de bestaande systemen, zonder de geïntegreerde structuur daarvan aan te tasten.

Een totaal van 120 boom- en struiksoorten werd aangetroffen; per boerderij stonden er gemiddeld 855 bomen (475 bomen per hectare) verdeeld over gemiddeld 21 soorten. De soorten *Cordia africana*, *Eucalyptus camaldulensis*, *Milletia ferruginea* en *Euphorbia candelabrum* kwamen in 88% van de boerderijen voor. De eerste twee soorten, samen met *Podocarpus falcatus,* zijn de meest voorkomende bomen (61% van de totale boompopulatie). De hoge boomdichtheid kan worden toegeschreven aan de dichte aanplant van eucalyptusbomen die als grensmarkering of houtkavel functioneren. Bomen die verspreid op het land staan zijn vaak inheemse soorten als *C. africana* en. *M. ferruginea,* die de voorkeur verdienen van boeren vanwege hun complementariteit ten opzichte van gewassen.
Evenals bij de gewassen is ook de diversiteit aan bomen niet gelijkelijk verdeeld over de verschillende percelen van de boerderijen. Koffie heeft het grootste aantal geassocieerde boomsoorten, gevolgd door enset en houtkavels. Percelen met handelsgewassen als chat, ananas, zoete aardappel en maïs hebben weinig geassocieerde bomen omdat schaduwbomen hierbij bewust worden vermeden.

De vier erftuin prototypes hadden duidelijk een verschillende boom samenstelling, hetgeen de lichteisen van de dominante gewassen reflecteert alsmede de fysische en socio-economische condities. Boerderij grootte, houtkavel grootte en toegang tot wegen beïnvloedde zowel de diversiteit als de dichtheid van bomen. De rijkdom aan boomsoorten van boerderijen nam toe met de grootte van de boerderijen en hun toegankelijkheid. De dichtheid van bomen nam toe met houtkavel oppervlak maar de uniformiteit ervan nam af omdat de houtkavels gedomineerd werden door dicht op elkaar geplante eucalyptus. Boerderijen met een goede toegang tot wegen hadden weinig boom soorten en een lage boom dichtheid, maar de uniformiteit was hoger omdat die boerderijen prioriteit gaven aan marktbare gewassen.

Het gemiddelde houtvolume per erftuin was 24 m^3 ha^{-1}, maar met veel variatie tussen dorpjes en boerderijen. Op veldgrenzen en in houtkavels zijn bomen dicht op elkaar gezet, maar binnen in velden en in graslanden staan ze verspreid. Deze verspreide bomen bevatten veel hout, 31% van de totale staande houtvoorraad. De variatie in houtvolume tussen dorpjes en boerderijen werd veroorzaakt door ecologische en socio-economische factoren, met name altitude, toegang tot wegen, en bedrijfsgrootte.

De belangrijkste resultaten van de studie zijn gesynthetiseerd in het laatste hoofdstuk. In de erftuinen zijn in totaal 198 gewassoorten en 7 gedomesticeerde diersoorten (vee) aangetroffen. De diversiteit aan gewassen, het meerjarige karakter, de hoge diversiteit en volume aan bomen, de aanwezigheid van vee, en de interactie tussen de verschillende compartimenten zijn de belangrijkste redenen voor de duurzaamheid en de stabiliteit van deze systemen.
Door de aanwezigheid van verschillende functionele groepen van gewassen kunnen veel huishoudens voldoende inkomen genereren. Van alle gewassen hebben enset en koffie de grootste economische en ecologische waarde. Enset is een voedselgewas met doorgaans een hoge opbrengst, wat het geschikt maakt voor toepassing voor de zelfvoorzienende landbouw. Koffie is het voornaamste handelsgewas en is belangrijk voor de regionale en nationale economie, omdat het productieproces en de handel veel werkgelegenheid met zich meebrengt. De combinatie van deze twee inheemse meerjarige gewassen en hun dominante voorkomen dragen bij aan de socio-economische en ecologische duurzaamheid. Bomen voorzien de huishoudens van hout, voedsel,

veevoer en geld. Bovendien zijn ze van ecologisch belang (ze zorgen voor schaduw, mulch, recycling van nutriënten, bodem en waterconservering, en verbeteren van het microklimaat), hetgeen bijdraagt aan de stabiliteit van deze systemen. Vee is een bron van eiwitten en levert geld op, maar zorgt ook voor de benodigde mest ter handhaving van de productiviteit van de bodem.

Recente veranderingen in het landgebruik die het gevolg zijn van een toegenomen commercialisering en toegenomen druk op het land kunnen leiden tot een afname van het voorkomen van enset, koffie en bomen in de erftuinen. De afname in het aandeel van deze meerjarige gewassen en hun vervanging door eenjarige gewassen kan een negative invloed hebben op de ecologische voordelen van deze geïntegreerde en complexe systemen en kan een bedreiging vormen voor hun duurzaamheid op lange termijn. Mogelijke verbeteringen van deze systemen moeten dan ook het geïntegreerde karakter in stand houden. Onderzoek en ontwikkelingsactiviteiten kunnen zich het best richten op het ontwikkelen van technieken voor de integratie van hoogwaardige gewassen in deze systemen, zonder hun eenheid aan te tasten.

Curriculum Vitae

Tesfaye Abebe was born in a small and old town named Boru Silassie, which is located in the suburbs of Dessie, Wollo, Ethiopia. He received his primary and secondary education in Dessie and joined Addis Ababa university where he later obtained his BSc degree in Plant Sciences from the then Alemaya College of Agriculture in 1984.

After graduation, he was employed as a Graduate Assistant at the Awassa College of Agriculture where he is still working. In 1987-88 he did his MSc study in Tropical Forestry, specialization Social Forestry at the department of Forestry, Wageningen Agricultural University. Almost a decade later he came back to Wageningen to pursue his PhD study in a sandwich program.

In his 20 years of service at the Awassa College of Agriculture, the author has served the college at different capacities: as a Graduate Assistant, Assistant Lecturer, Lecturer and then as an Assistant Professor since 1994. In 1990-94 he has served as chairman of the department of Plant Sciences. Besides teaching, Tesfaye has been involved in agroforestry and forestry researches, particularly in the areas of, screening of multipurpose trees for agroforestry, selection of fast growing firewood tree species and tree-crop interactions in agroforestry. Some of the results of the studies have been published and others are still to come.

The author has participated in various professional workshops, conferences and training courses. He has been a research fellow for the Regional Soil Conservation Unit of the Swedish International Development Agency in Nairobi to analyze Agroforestry and Soil and Water conservation curricula in the agricultural colleges of Eastern Africa. He has also worked as a consultant to some governmental and non-governmental organizations in Ethiopia. Besides, Tesfaye has served as member of the steering committee of the African Network for Agroforestry Education (ANAFE) from 1995 to 1998.